



Backup



RCS Action Item Disposition

- **MT-17, Propellant Slosh, Ken Seidemann**
 - **Status: Closed**
 - **Propellant Tank Selected with Metallic Diaphragm to Mitigate Both Gross and Fine Motion Propellant Slosh**
 - **This is the Best that Can Be Done to Mitigate Liquid Motion**
 - **Full Slosh Analysis to be Completed By CDR**
 - **Frequency and Amplitude of Disturbance Torques**
 - **Goal is Frequency Greater Than 1 Hz for Jitter**
 - **Amplitude Results in Nutation and Spin Rate Variations**
 - **Resultant Observatory Motion**
 - **Effects on Observatory Science Collection**
 - **In-Scan and Cross Scan Error Budget**

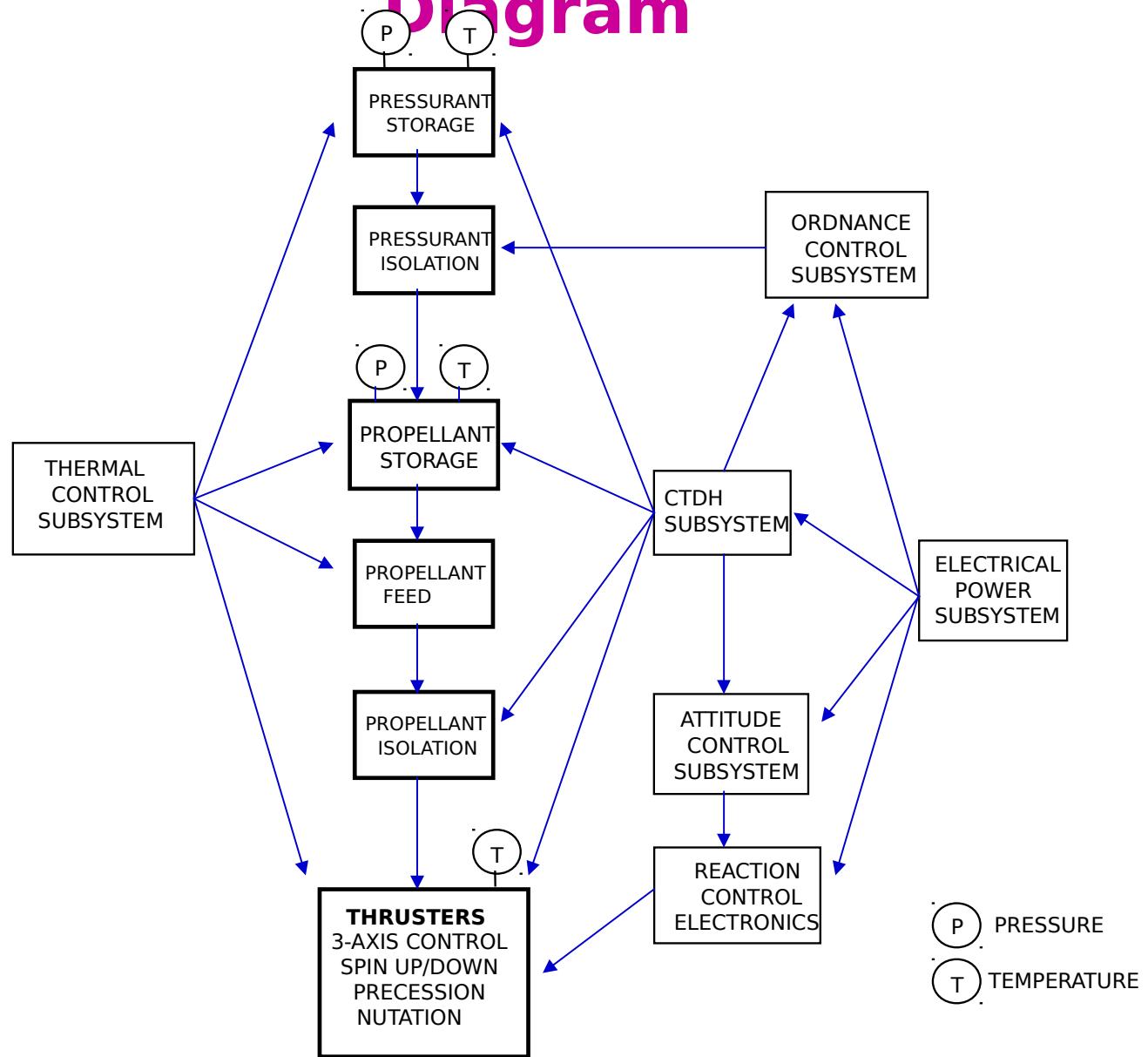


Propulsion PDR Peer Review

- **Peer Review Conducted October 10, 2001**
- **Attendees:**
 - NASA Goddard - Gary Davis, Jose Bolleck
 - NRL - Paul Delahunt, Ron Mader, Russ Barnes, Mark Johnson, Aaron Chilbert, John Schaub, Bob McClelland, Bob Baldauff, Albert Bosse, Joe Hauser
- **Independent Design Reviews Also Conducted With Propulsion Experts That Could Not Attend**
 - Applied Physics Laboratory - Larry Mosher
 - NRL - Ron Wojnar, Paul Cary
- **Major Issues**
 - **Small Hydrazine Tank Causes Complexity and Cost**
 - High Number of Parts Including 5 Tanks
 - Packaging, Mass, and Cost Constraints
 - **Thruster Refurbishment Cost**
 - Concern That Labor Cost May Exceed Hardware Cost
 - **No MRD Propellant Margin Requirement**

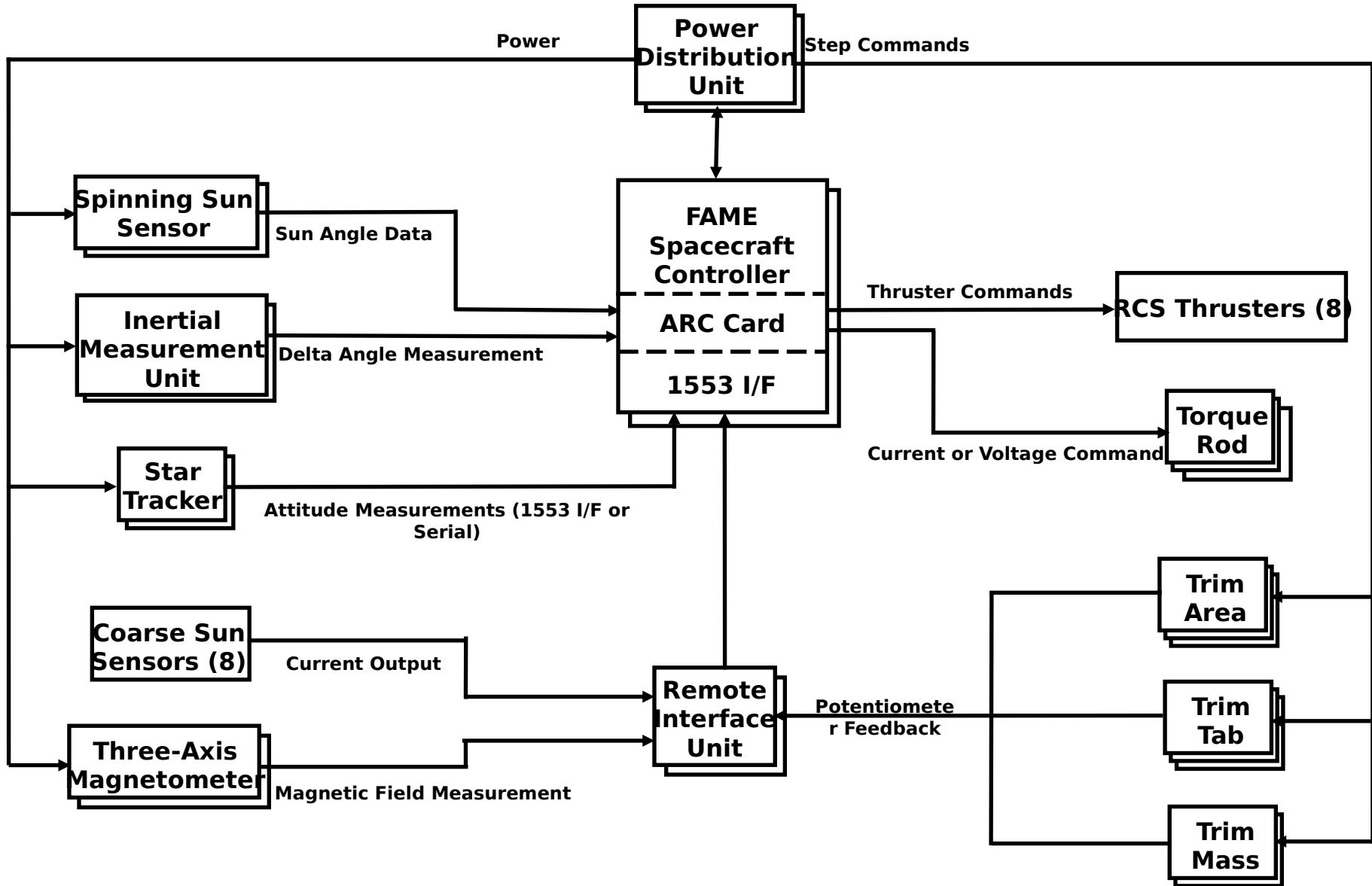


Propulsion Block Diagram



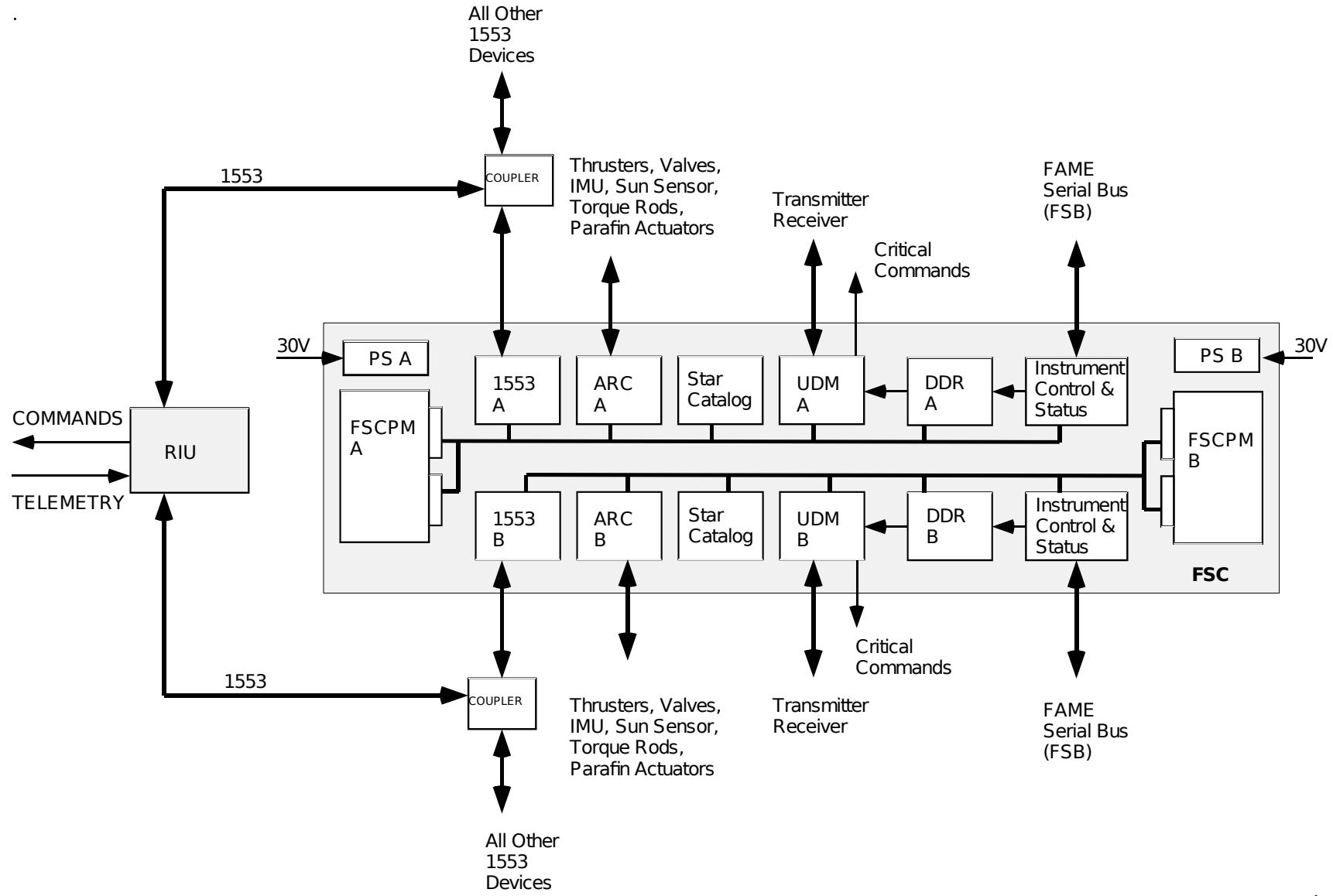


Detailed Block Diagram & Interfaces





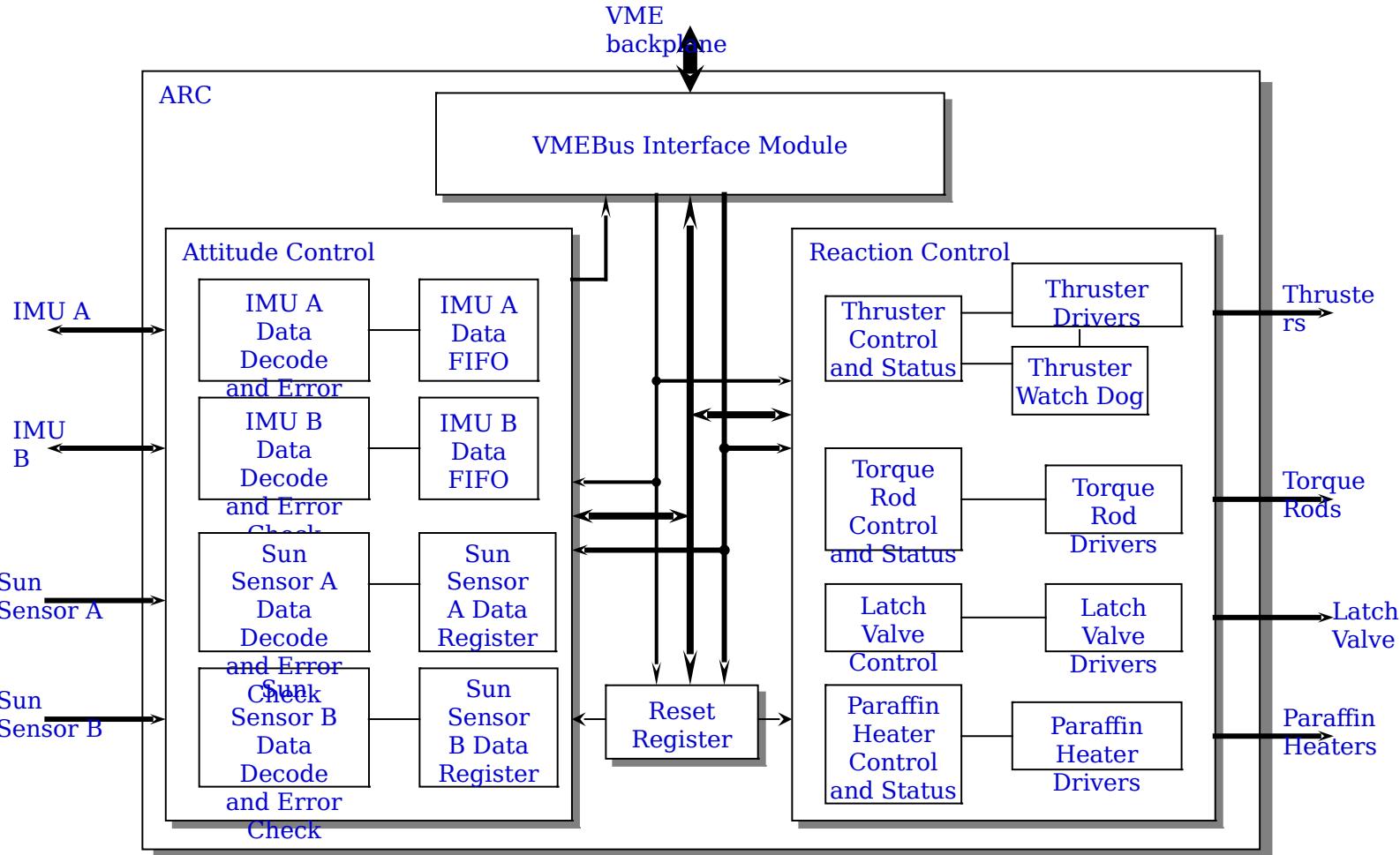
CTDH Block Diagram





ARC Block Diagram

Attitude and Reaction Control Board





Component Definitions

- **HTK, Hydrazine Tank**
- **PT1-5, Helium Pressurization Tanks 1-5**
- **PIV1, Pressure Isolation Valve 1**
- **PIV2, Pressure Isolation Valve 2**
- **HTSV, Helium Tank Service Valve**
- **HGSV, Hydrazine Tank Gas Service Valve**
- **HLSV, Hydrazine Tank Liquid Service Valve**
- **TSV, Test Service Valve**
- **HPT, Helium Pressure Transducer**
- **LPT, Liquid Hydrazine Pressure Transducer**
- **L, Latch Valve**
- **F, Filter**
- **Thruster 1 (5 lbf)**
- **Thruster 2**
- **Thruster 3 (5 lbf)**
- **Thruster 4**
- **Thruster 5**
- **Thruster 6**
- **Thruster 7**
- **Thruster 8**



Key Propulsion Derived Requirements

(1 of 3)

- Provide GEO Insertion From Delta II 7425 Launch Vehicle
 - Baseline Thiokol STAR 30BP Solid Rocket Motor
 - 1110 Kg Launch Vehicle Throw Weight
 - 1478 m/s GEO Insertion Maneuver
- Provide Vehicle 3 Axis Attitude Control
 - Spin Control (About Vehicle Z Axis-Roll)
 - Requires Pure Torque Couples
 - Spin Stabilize for Solid AKM Firing 40-60 RPM
 - Rotation Control for Science Mission
 - 1 Revolution Per 40 Minutes
 - Active Nutation Control (ANC)
 - Pre Solid Rocket Motor Firing
 - Spin Axis Precession (SAP) Control
 - Pre Solid Rocket Motor Firing
 - Correct for Delta V Thrust Misalignment With CG
- Active Science Mission Thruster Control is Not Required
 - Spin Rate Control, Solar Precession Back-up, Nutation Control



Key Propulsion Derived Requirements

(2 of 3)

- Provide Delta V Thrust Through + Z Axis (Velocity Vector) for Orbital Maneuvers
 - Correct Delta II 7425 Launch Vehicle Insertion Error
 - 1st/2nd Stage Pointing Error
 - 3rd Stage (STAR 48) Pointing and Impulse Errors
 - Correct Transfer Stage SRM (STAR 30BP) Pointing and Impulse Errors
 - Errors Requires Additional Impulse Capability From the On-Board Propulsion System
 - Stage Pointing Errors Produce Inclination Changes
 - Acceptable to $\pm 30^\circ$ With No Correction
 - Within Ground Station Antenea Tracking Capability
 - De-Orbit Transfer Stage Before Science Mission
 - Provide Stationkeeping (Drag Make Up) Delta Velocity
 - No North-South Stationkeeping Requirement (Allows Inclination Drift)
 - Passive East-West Stationkeeping for GEO Orbit Position
 - GEO Orbit Optimized For One TBD Maneuver Each 15 Months



Key Propulsion Derived Requirements



(3 of 3)

- Mono-Propellant Hydrazine Propellant System
 - Moderate Mission Total Impulse Requirements
 - Blowdown Pressurization
- Positive Expulsion Tank Required for Precision CG Alignment During Expulsion
 - Science Mission Requirement
 - Eliminates Passive PMD Designs (i.e., Vanes, Sumps)
- Drop Off SRM Stage Due to Uncertainty in Post Burn Mass Properties
 - Science Mission Requirements for CG Knowledge & Alignment
- De-Orbit in Accordance With NASA Policy Directive (NPD) 8710.XX for Orbital Debris Mitigation
 - GEO Is an Active Orbit Requiring Removal of Orbital Debris
 - 300 Km Above or 500 km Below GEO Disposal Orbits
 - Applies to Solid Apogee Transfer Stage
 - Final Disposal of FAME Vehicle



Propulsion Requirements Matrix (1 of 2)



Item	Requirement	Description
3 Axis Attitude Control	Yes	Top Level ADCS Requirement
Spacecraft Delta Velocity	67 m/s	Top Level Propulsion Requirement Mission Orbit Insertion and De-orbit
Single Fault Tolerant Design	Yes	Mission Success - Proposal
Mission Life	5 Years	Mission Success - Proposal
Component Qualification	Prototypical	Margin over Worst Case Mission and Launch Environments
Component and System Verification	NCST-TP-FM001	FAME Test Plan
System Delivery Date	6/15/03	Supports Integrated Mechanical Schedule
Cost and Program Risk	Minimize	Lowest Cost and Risk Within Budget Allocations
Maximum Propellant Weight	49.9 Kg	Establishes Tank Size
EWR 127-1	Compliant/Waived	TBD Dated Version
Component Safety Factors	2.5:1	Derived from Mil-Std-1522 and EWR 127-1
Mechanical Faults To Activation	2	Single Fault Tolerant, EWR 127-1
Electrical Faults to Activation	3	Dual Fault Tolerant, EWR 127-1
Adiabatic Detonation	None	Mission Success Requirement
Maximum Water Hammer Surge Pressure	Proof Pressure	Mission Success Requirement, Exceeds System MEOP, Defines System Proof
Spacecraft Pitch Rate	TBD °/sec	ADCS Requirement used for Thruster Sizing and Propellant Slosh Analysis
Spacecraft Yaw Rate	TBD °/sec	ADCS Requirement used for Thruster Sizing and Propellant Slosh Analysis
Spacecraft Roll Rate	TBD °/sec	ADCS Requirement used for Thruster Sizing and Propellant Slosh Analysis
Thruster Control Authority Margin	25%	ADCS Requirement used for Thruster Sizing and Location
Simultaneous Thruster Firings	5	Used for Hydraulics Analysis
Maximum Dry Weight	27.2 kg (60 lb)	Spacecraft Spec Requirements
Vibration	NCST-D-FM017	Environmental Requirement
Shock	NCST-D-FM017	Environmental Requirement
Static Acceleration	NCST-D-FM017	Environmental Requirement
Minimum Temperature	7 C	No Hydrazine Freezing
Maximum Temperature	30 C	Establishes Tank MEOP
Component Cleanliness	Mil-Std-1246 100A	Spacecraft Spec Requirements
Maximum Power	TBD W	Spacecraft Spec Requirements
Bus Voltage (Vbus)	24 < Vbus < 36	Spacecraft Spec Requirements
Maximum 1N Thruster Pulses	< 200000	Thruster Spec Requirement
Maximum 22N Thruster Pulses	< 60000	Thruster Spec Requirement
Minimum 22N Impulse Bit	.04 N sec	Thruster Spec Requirement
Minimum 1N Impulse Bit	.02 N sec	Thruster Spec Requirement
Maximum Thrust Level	22 N or 1 N (TBR)	Thruster Spec Requirement, Open ANC Thruster Trade
Minimum Burn Duration	20 ms	Thruster Spec Requirement
Maximum Delta V Maneuver Time	40 minutes	10° GEO Burn Arc. Used for Delta V Thruster Sizing
Maximum Burn Duration	40 min	Thruster Spec Requirement
Thruster Cold Starts	0	Thruster Spec Requirement, EPS and Software Design
22N Total Impulse Per Thruster	< 100,000 N-sec	Thruster Spec Requirement
1N Total Impulse Per Thruster	< 80,000 N-sec	Thruster Spec Requirement



Propulsion Requirements Matrix (2 of 2)



Item	Requirement	Description
Thruster Mechanical Alignment	0.5°	For ADCS Analysis
Thruster Alignment Knowledge	0.1°	For ADCS Analysis
Plume Contamination	TBD % EOL Data Loss	Instrument Spec Value
Component External Leakage	< 5E10-5 scc/sec He	Determines Propellant/ Pressurant Requirements and Spacecraft Error Torque
Valve Leakage Per Seat	< 1E10-5 scc/sec He	Determines Propellant/ Pressurant Requirements and Spacecraft Error Torque
Tank Design	EWR 127-1,Mil-Std-1522	Derived from Mil-Std-1522 and EWR 127-1
Propellant Center of Gravity	10 mm (TBD)	For ADCS Analysis
Propellant Slosh Amplitude	.1 mm (TBD)	For ADCS Analysis
Propellant Slosh Frequency	TBD > f < TBD	For ADCS Analysis, Goal of >1 Hz for Jitter Reduction
Launch Tower Fill/Drain Access	Yes	Contingency Propellant Offloading Requirement
Propulsion Ground Support Equipment	Yes	Pressurant Control Console, Vacuum Cart
Fill Valve Protective Covers	Yes	Remove Before Flight Ground Support Equipment
Thruster Protective Covers	Yes	Remove Before Flight Ground Support Equipment
Tank Protective Cover	Yes	Remove Before Flight Ground Support Equipment
SRM Delta V	1478 m/s	Top Level Propulsion Requirement
SRM Maximum Total Weight	542.7 kg (TBR)	Thiokol STAR 30BP Maximum, Spacecraft Spec Requirements
SRM Case Leakage	< 1E10-4 scc/sec He	SRM Spec Requirement
SRM Maximum Acceleration	7 g's	Spacecraft Spec Requirements
SRM Maximum Offload	20%	SRM Spec Requirement
SRM Maximum Spin Rate	60 RPM	SRM Spec Requirement
SRM Temperature	5 to 32°C	SRM Spec Requirement
SRM Maximum Differential Temperature	10° C	SRM Spec Requirement
SRM Maximum Burn Time	300 sec	SRM Spec Requirement
SRM Static Balance	TBD oz in	Spacecraft Spec Requirements
SRM Dynamic Balance	TBD oz in2	Spacecraft Spec Requirements
STAR Motor Alignment	0.5°	For ADCS and Mission Analysis
STAR Motor Alignment Knowledge	0.1°	For ADCS and Mission Analysis
STAR Motor Case Temperature	370 C	For Thermal Analysis and Design
STAR Motor Thermal Model	Yes	Required for Thermal Analysis
SRM Mass Simulator	Yes	System Verification and test
SRM Thermal Simulator	Yes	Thermal Integration Support
SRM Shipping Container	Yes	Lease From Thiokol
SRM Ground Support Equipment	Yes	Lease From Thiokol Turn Over Stand, Proof and Leak Test Fixture
Thruster Alignment Verification Plan	Yes	Integration Support
SRM Alignment Verification Plan	Yes	Integration Support
SRM Interface Verification Plan	Yes	Integration Support
Propellant Servicing Equipment	Yes	Support Propulsion Fueling Effort
Propellant Servicing Procedures	Yes	Range Safety Verification
Range Safety Verification Support	Yes	Range Safety Verification



Propellant System Safety Requirements



- **For Range Safety Compliance (EWR 127-1) Safe Containment of Hazardous Commodities**
- **All Tanks Meets MIL-STD-1522A Design and Qualification Requirements**
- **Aluminum Propellant Tank Design, 1.5:1 Flight, >4:1 Ground Operations, All Welded Construction Including Aluminum Diaphragm**
- **Isolation of Helium Pressurization System From Hazardous Propellant**
 - Pyrotechnic Isolation Valve
 - Latch Valve
 - Dual Seat Thruster Valves
- **Helium Pressure Tank LBB Non Hazardous Commodity**
 - Greater 2:1 Flight & Ground Operations
 - All Welded Construction is Possible With Design Modification
 - Currently Contains MS Mechanical Fitting and EPR O-Ring
- **Passive Blowdown Pressurization**
 - Active Pressurization Systems Require Higher Safety Factors or Failure Tolerance to Activation Including Relief Valves
- **Mechanical Flanges Under Trade Study (Existing Multiple O-Ring Designs)**



Interface Summary (1 of 2)

- **CTDH**
 - Operate 6 1N (0.2 lb) Thrusters
 - Operate 2 22N (5.0 lb) Thrusters
 - Operate 1 Latch Valve
 - Monitor 2 Pressure Transducers
 - Monitor and Condition Signals for 17 Propulsion Temperatures
 - RTD Temperature Sensors
- **Ordnance**
 - Operate Two Pressure Isolation Valves (Pyrotechnic)
 - Operate and Actuate 2134B Safe and Arm Device for STAR 30BP
- **Electrical Subsystem (Power, RCE)**
 - Pyrotechnic Valves
 - Pressure Monitoring
 - Valve Drivers
 - Catalyst Bed Heaters
 - Pressure Transducer



Interface Summary (2 of 2)

- Thermal Control
 - Maintained Propellant Temperature @ Ground: 40° to 120°F, Flight: 40° - 104°F (Freeze Point N2H4 is 35.6°F)
 - Protect Line Heaters, MLI, Tank, Valve Heaters,
 - Catalyst Bed Heaters
 - Minimize Tank Thermal Cycles (Both Number and Depth)
 - Cycles Work Harden Metal Diaphragm
 - Show 4 Times Minimum Safety Factor for Cycles to Failure
 - Vendor Analysis or Test
 - Solid Rocket Motor Thermal Control
- Maintain Center of Mass Knowledge
 - Propellant Location
 - SRM Mass Properties
- Plume
 - Minimize Plume Contamination to Observatory
 - Minimize Plume Heating
 - Minimize Plume Pressure Loading Effects



Propulsion Command & Telemetry

Commands	Type
Pressure Isolation Valve 1 Enable	Discrete Level Hold
Pressure Isolation Valve 2 Enable	Discrete Level Hold
Pressure Isolation Valve Pre-Arm	Discrete Level Hold
Pressure Isolation Valve 2 Pre-Arm	Discrete Level Hold
Pressure Isolation Valve 1 Arm	Discrete Level Hold
Pressure Isolation Valve 2 Arm	Discrete Level Hold
Pressure Isolation Valve 1 Fire	Discrete Level Hold
Pressure Isolation Valve 2 Fire	Discrete Level Hold
AKM Enable A	Discrete Level Hold
AKM Enable B	Discrete Level Hold
AKM Pre-Arm A	Discrete Level Hold
AKM Pre-Arm B	Discrete Level Hold
AKM Arm A	Discrete Level Hold
AKM Arm B	Discrete Level Hold
AKM Fire A	Discrete Level Hold
AKM Fire B	Discrete Level Hold
Latch Valve Close	100 ms Pulse
Latch Valve Open	100 ms Pulse
Thruster 1 On	Variable Pulse
Thruster 2 On	Variable Pulse
Thruster 3 On	Variable Pulse
Thruster 4 On	Variable Pulse
Thruster 5 On	Variable Pulse
Thruster 6 On	Variable Pulse
Thruster 7 On	Variable Pulse
Thruster 8 On	Variable Pulse

Telemetry	Type
Hydrazine Tank Temp 1	Low Level Analog
Hydrazine Tank Temp 2	Low Level Analog
Thruster 1 Temp	Low Level Analog
Thruster 2 Temp	Low Level Analog
Thruster 3 Temp	Low Level Analog
Thruster 4 Temp	Low Level Analog
Thruster 5 Temp	Low Level Analog
Thruster 6 Temp	Low Level Analog
Thruster 7 Temp	Low Level Analog
Thruster 8 Temp	Low Level Analog
Liquid Pressure Transducer Temp	Low Level Analog
Helium Pressure Transducer Temp	Low Level Analog
Helium Tank 1 Temp	Low Level Analog
Helium Tank 2 Temp	Low Level Analog
Helium Tank 3 Temp	Low Level Analog
Helium Tank 4 Temp	Low Level Analog
Helium Tank 5 Temp	Low Level Analog
Latch Valve Status	Discrete Bi-Level
Liquid Pressure Transducer Pressure	0-5 V
Helium Pressure Transducer Pressure	0-5 V



Propulsion Power Requirements

- All Values Listed are Individual Components at 70°F and 28 VDC
- 0.2 lb Thrusters
- Valve Heaters 2.0 W (TBD Ohms)
- Bed Heaters 1.5 W Max (330 Ohms)
- Valve Actuation (Total Each Thruster) 9.0 W (2, TBD Ohm Coils in Parallel)
- 5.0 lb Thrusters
- Valve Heaters 2.0 W (TBD Ohms)
- Bed Heaters 2.4 W Max (330 Ohms)
- Valve Actuation (Total Each Thruster) 20.9 W (2, 75 Ohm Coils in Parallel)
- Latch Valve (40 ms Pulse) 52 W (2, 16 Ohm Coils in Parallel)
- Pyrotechnic Isolation Valve 112 W (4 Amps)
- Pressure Transducer 1.0 W



ADCS Control and Knowledge Requirements



Mode	Support Function	Control/Knowledge Parameter	Control Requirement	Knowledge Requirement	Knowledge Comments
Inertial Pointing	AKM Spin-Up Initialization	AKM Burn Vector & Roll Angle	+/- 1 Deg	+/- 0.1 Deg	SSS, ST, IMU, KF Derived Requirements
	Orbit Adjustment Burns	Attitude	+/- 0.5 Deg	+/- 0.05 Deg	ST, IMU, KF Derived Requirements
Closed Loop Spin Rate Control	Control Of Spin Rate	Spin Rate	+/- 100 mrad/sec	+/- 50 mrad/sec	IMU Derived Requirements
Active Nutation Control	Control Of Nutation Angle	Nutation Angle	+/- 0.25 Deg	+/- 0.1 Deg	IMU & Inertia Derived Requirements
Spin Axis Precession	Pointing To AKM Burn Vector	Spin Axis Orientation & Roll Angle	+/- 1 Deg	+/- 0.5 Deg	SSS Sun Angle, SSS Roll Angle Update, KF Initialization, IMU Propagation Derived Requirements
Safe Hold	Pointing To Sun Vector	Sun Angle	+/- 20 Deg	+/- 10 Deg	CSS Derived Requirements



Propulsion System Trades

- **Solid Apogee Kick Motor (AKM) and Monopropellant Hydrazine Propulsion System Selected for FAME Mission Orbit Insertion**
- **Other Propellant Systems Considered to Perform the FAME Mission Include:**
 - **Solid AKM and Cold or Warm Gas Systems**
 - **Volumetrically Large and Massive for FAME Total Impulse**
 - **All Electric Propulsion**
 - **Power Limited Design Has Long Orbit Transfer Time**
 - **Solid AKM and Electric Propulsion**
 - **Low Thrust Good for Precision Impulse Bit**
 - **High System Complexity**
 - **Separate Xenon Propellant Feed System Required**
 - **High Power Required and With Special Power Electronics**
 - **6 Month Minimum Orbit Transfer Time**
 - **All Bi-Propellant Upper Stage Options (MMH/NTO/N2H4, and NTO/N2H4)**
 - **Higher Specific Impulse Results in Less Propellant Weight**
 - **Separable and Non-Separable Propulsion Stages**
 - **High System Complexity and Cost**
 - **Two Propellant Feed Systems**
 - **Higher Force and Impulse Bit Thrusters Not Suitable for Precise ACS Control**



Trade Space

Options	Description	LV	Upper Stage	Propulsion System	Transfer Time (days)	Total Cost	Cost Savings	Mass Savings (lb)	Comments	Option Status
-1	Previous Design	60.2	1.8	4.3	1	66.3	0	0		Closed
0	Delta 7925	60.2	0.8	3.7	1	64.7	1.6	50	Use Existing Tiros STAR 37XFP and Qualified 31 inch tank	Open
1	Delta 7420 LEO to GEO Transfer with All Electric Propulsion (EP)	51	0	10	1350	61	5.3	3500	Power Limited. Reaction Whee or Thruster Gimbal required. Cost Savings does not justify the transfer time	Closed
2	Delta 7426 Sub Synch Wth Solid and EP	53.8	1.5	7.7	200-400	63	3.3	700-1300	Power Limited. Reaction Whee or Thruster Gimbal required. Cost Savings does not justify the transfer time and system complexity	Closed
3	Delta 7425 Super Synchronous Transfer Wth Solid and EP	53.8	1.5	7.7	200-400	63	3.3	700-1300	Power Limited. Reaction Whee or Thruster Gimbal required. Cost Savings does not justify the transfer time and system complexity	Closed
4	Delta 7425 Super Synchronous Transfer Wth Hydrazine and EP	53.8	0	7.7	300-400	61.5	4.8	1000	Power Limited. Reaction Whee or Thruster Gimbal required. Cost Savings does not justify the transfer time and system complexity	Closed
5	Delta 7420 Wth Bi-prop Dual Mode Upper Stage	51	0	6	1	57	9.3	50 - 500	Packaging is more Challenging Different Tank Volumes for fuel and oxidizer	Closed
6	Delta 7420 Wth Bi-prop MMH/NTO Upper Stage and Monopropellant Hydrazine ACS	51	0	7	1	58	8.3	0-400	Bi-prop Tanks are of Equal Volume. Monopropellant Hydrazine for ACS in separate tank.	Closed
7	Delta 7420 Wth Bi-Prop Separable Bi-prop stage with Permanent Hydrazine ACS	51	0	8	1	59	7.3	0-150	Bi-prop stage must be placed a Disposal Orbit	Closed
8	Delta 7425 Highly Eccentric Orbit (HEO), 400 Mile Perigee, Near Lunar Apogee	53.8	0	2	1	55.8	10.5	0	10-15 day Orbit Period dependent on Apogee Altitude Causes significant change to mission science collection orbit. Effects of the moon and earth must be accounted for	Closed

Cost Savings Represents Propulsion Cost Savings Only



Tank Trades- Geometry

- **Tank Geometry**
 - An Oblate Spheroid is Desired but Has Limited Availability
 - Reduces Spacecraft Overall Height Allowing Preferred Sun Angle Between the Sun Shield and Payload
 - Mounting Options Include Boss and Girth (Tabs or Skirt)
 - Tank Volume Determination Requires Quantification of Propellant and Pressurization System
 - Single Blowdown Tank vs. Augmented Pressurization Tank
- Implication of Oversizing the Hydrazine Tank
 - Lowers the System Blowdown Ratio
 - Smaller BOL to EOL Thrust Variation
 - Effects on Nutation Control (Requires High Thrust)
 - Effects on Minimum Impulse (Requires Low Thrust)
 - Can Overfill to Correct Blowdown Ratio
 - Mass Penalty for Unused Propellant
 - An Oversized Tank is an Excellent Reservoir for Mass Margin
 - Contingency Operations, Science Mission ACS, or Extended Mission



Tank Trades PMD Selection

- **PMD Selection Limits Tank Availability**
 - **Passive PMD Is Not Possible (Accelerations, Spin, and CG Control)**
 - **Traded Elastomeric Tank Bladder vs. Metal Diaphragm**
 - **Elastomeric Tank Bladder Not the Baseline Due to CG Uncertainty**
- **Single Use Metal Diaphragm Characteristics**
 - **Higher ΔP From Gas to Liquid**
 - **Better Cg Control During Accelerations**
 - **Single Use Only**
 - **Eliminates Gross Mass Motion Slopsh**



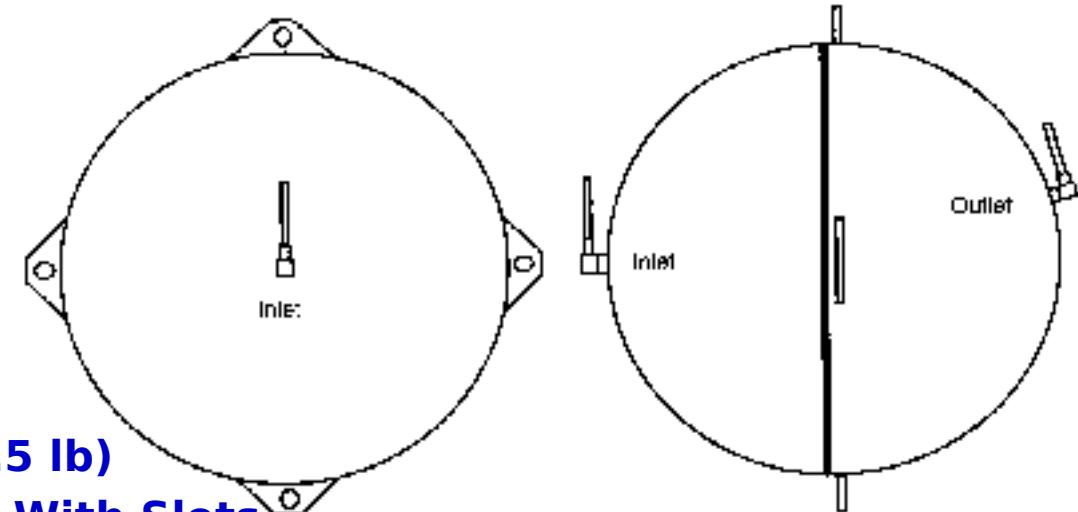
Tank Trades - Delivery

- **New Design and Qualification Was Possible In Spring 2001**
 - **Oblate Spheriod Shape With Optimized Mass and Expulsion Characteristics**
 - **Single Tank for Pressure Gas and Propellant**
 - **Active CBD Solicitation For Proposals**
 - **New Tank Design and Qualification Requires 24 Months Delivery**
- **Current Cost and Delivery Schedule Requires a Qualified Heritage Design**
 - **Program Schedule Supports “Off-the-Shelf” Tank Procurement**
 - **Multiple Designs Available from Atlantic Research and Arde**



Elastomeric Diaphragm Tank Option

- **PSI P/N 80388**
- **Maximum Expected Operating Pressure (MEOP) 350 psia**
- **Proof Pressure 527 psia, Minimum Burst 700 psia**
- **Qualified Propellant Load of 72.56 kg (160 lb)**
- **Geometry**
 - **57.15 cm (22.5 in)**
 - **Outside Diameter**
 - **Spherical with Offset**
 - **Polar Outlet Tube**
 - **Volume 91.1 Liters**
 - **(5555 cu in)**
 - **Tank Weight 7.03 kg (15.5 lb)**
 - **Four Girth Mounted Tabs With Slots**
 - **AF-E-332 Elastomeric Bladder**
- **Designed and Previously Flown for Koreasat, CENTAUR, TOMS-EP, ROCSAT, KOMPSAT, INMARSAT 3, GGS**
- **Full Mil-Std-1522 Design, Analysis, and Qualification Testing**
 - **One Known Safety Waiver Required for Last Girth Weld Stress Relief**





Small Metal Diaphragm Tank (Option)

- ARDE P/N 4687
 - 19 x 20 Inch Near Sphere (3182 Cubic In, Liquid Volume)
- Maximum Expected Operating Pressure (MEOP) 400 psig
- Proof 450 psia, Minimum Burst 600 psia
 - Qual Burst 1196 (by Similarity)
 - Polar Inlet and Outlet Tubes
 - Bolted Flange and Slip Boss Mounting
 - Tank Weight 8.3 kg (18.3 lb)
 - Cryo-Formed 301 Shell, 304 Ring Stabilized Metal Diaphragm
- Developed for NRL Sandia ODES Program
 - Recently Qualified for ORBCOMM IV
- Requires Secondary Pressurization System
 - Fill tank to 97% with Hydrazine
 - 112 lb Hydrazine Maximum Capacity



Big Metal Diaphragm Tank (Option)

- **Atlantic Research Corporation (ARC) P/N AO882300**
 - **31 inch Near Sphere (16,615 Cubic In)**
- **Maximum Expected Operating Pressure (MEOP) 318 psia**
- **Proof 472.5 psia, Minimum Burst 567 psia**
 - **Polar Inlet and Outlet Tubes**
 - **Tank Weight 27.2 kg (60 lb)**
 - **Polar Boss Mounted with Threaded Receiver**
 - **AL 2219 Shell, AL 1100 Metal Diaphragm**
- **Currently Under Development for Boeing**
- **Large Size Accommodates Blowdown Pressurization**
- **Large Tank is Difficult to Package in the Current Design**



Pressure Trades (1 of 2)

- Traded Nitrogen and Helium Pressurization Gasses (Trade Complete)
 - Nitrogen Selected for the Delta 7925 Design (Not Mass Limited)
 - 2.0 lb Nitrogen Required
 - Nitrogen Has Almost Three Times Better Leakage Tolerance
 - Traded as Dual Use for Cold Gas Attitude Control Thrusters
 - Better Thermal Characteristics
 - More Ideal Gas Simplifies Flight System Performance Estimation
 - Helium Selected for Current Smaller Delta 7425 Observatory Design
 - 0.2 lb of Helium Required
- Active Pressurization System (Trade Completed)
 - Chopper Shuttle Valves with Known Control Volume
 - Parallel Valves Required for Reliability
 - CT&DH System Impacts Significant
 - Software Development
 - Requires Hydrazine Tank Relief Valves or Pyrotechnic Isolation Valves
 - Three Faults to Catastrophic Hazard (Hydrazine Tank Rupture)
 - Added Mass, Cost, Schedule, and Complexity



Pressure Trades (2 of 2)

- Optimize Current Pressurization Storage System (Trade On-going)
 - Current Configuration Has 5 Pressure Tanks
 - Uses Identified Qualified Hardware
 - Minimizes Mass and Packaging Constraints
 - Over Six Other Pressure Tank Systems Compared
 - Other Qualified Tanks to Be Investigated
 - Other Modifications to Qualified Tanks to Be Investigated
 - One Option is to Use the Liner of a Composite Overwrapped Design
 - Other Potential Vendors and Designs Are Possible
 - Development Tanks Most Likely Do Not Meet the 12 Month Schedule
- Multiple Repressurization System (Trade To Be Performed)
 - Multiple Pressure Tanks Isolated From the Propellant Tank in Series
 - Activate One Tank at a Time Until Pressure Depletes
 - Allows Progressively Higher Storage Tank Pressures
 - Smaller Total Volume



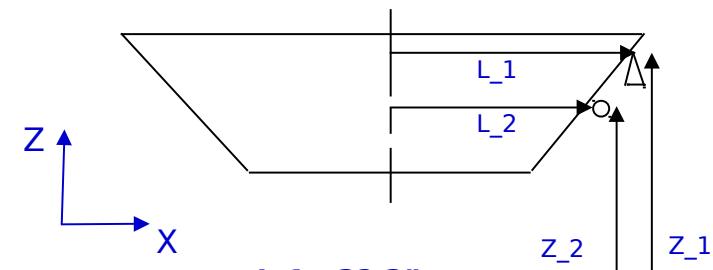
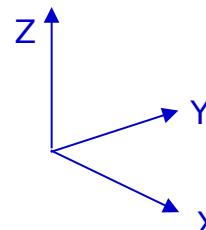
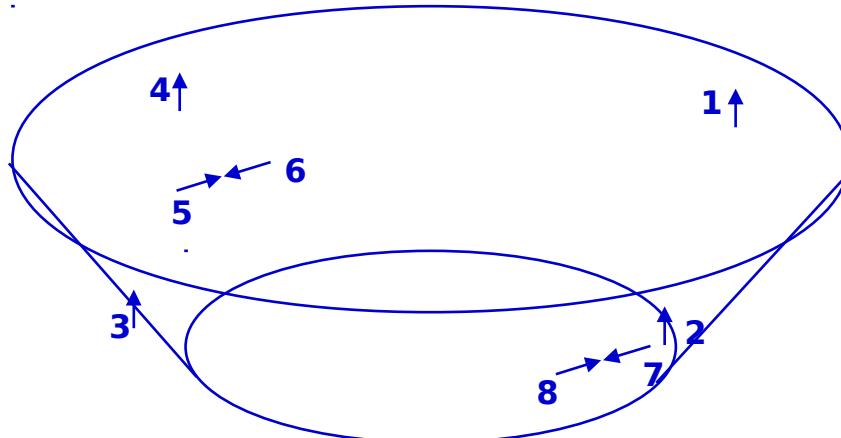
Propulsion Trades - Hydrazine Thrusters



- **Multiple Designs and Vendors Including**
- **MR-111C 4N (1.0 lbf)**
 - Flown on Clementine
- **MR-111E 2N (0.5 lbf) MR-103C 1N (0.2 lbf)**
 - Small Impulse Bit, but Being Discontinued by Manufacturer
 - $I_{bit\min} = .0044 \text{ N}\cdot\text{sec} @ 15\text{ms and } 100 \text{ psia}$
- **MR-103D 1N (0.2 lbf) Long Life Thruster Variant**
 - More Costly Than Warranted by FAME Mission Requirements
- **MR-103G 1N (0.2 lbf) IRIDIUM Design**
 - $I_{bit\min} = .0133 \text{ N}\cdot\text{sec} @ 15\text{ms and } 100 \text{ psia}$
- **MR-103H 1N (0.2 lbf) Smallest Impulse Bit**
 - Single Fast Acting Solenoid Valve Rather Than Dual Valves
 - High Cost ~\$80K
 - $I_{bit\min} = .0022 \text{ N}\cdot\text{sec} @ 15\text{ms and } 100 \text{ psia}$
- **ValveTech Consortium 0.2 lbf Low Cost Thruster**
 - Flight Demonstrated but Qualification and Delivery Status TBD



Thruster Configuration



L_1 = 32.3"
Z_1 = 72"
L_2 = 27.3"
Z_2 = 65.5"

Zc.m. w/AKM= 58"
Zc.m. w/dry AKM= 73"
Zc.m. w/o AKM/interstage= 81.4"

Thruster sizing			
1,3: 5 lbf			
2,4,5-8: 0.22 lbf			
ID	x	y	z
1	0	0	1
2	0	0	1
3	0	0	1
4	0	0	1
5	0	1	0
6	0	-1	0
7	0	-1	0
8	0	1	0



Thruster Usage

THRUSTER SELECTION

Function	Mode	Baseline Thruster Set
Spin-up/down	CLS	5-8
Active Nutation Control	ANC	1 and 3
Spin Axis Precession	SAP	1 or 3
ΔV Using ACS J ets	IP	1 & 3, Off-pulsed for X ctrl; 2,4 for Y ctrl, 5-8 for Z ctrl
3-Axis Deadband Control & Slew Maneuvers	IP	2,4, 5-8

IP=Inertial Pointing

CLS=Closed Loop Spin



Sample Jet Select Table

**Jet Selection Table
 for Vehicle
 Configuration
 Following
 Akm/Interstage
 Separation
 1= Cmd ON, 0= Cmd
 OFF
 “X” Indicates OFF by
 Cancellation With
 Opposing Jet**

Torque Cmd	Jet number										
	Yaw	Pitch	Roll								
				8	7	6	5	4	3		
Z	Y	X									
0	-1	-1	-1	0	1	X	X	0	0	1	0
1	-1	-1	0	0	1	0	1	0	0	1	0
2	-1	-1	1	X	X	0	1	0	0	1	0
3	-1	0	-1	0	1	X	X	0	0	0	0
4	-1	0	0	0	1	0	1	0	0	0	0
5	-1	0	1	X	X	0	1	0	0	0	0
6	-1	1	-1	0	1	X	X	1	0	0	0
7	-1	1	0	0	1	0	1	1	0	0	0
8	-1	1	1	X	X	0	1	1	0	0	0
9	0	-1	-1	0	1	1	0	0	0	1	0
10	0	-1	0	0	0	0	0	0	1	0	0
11	0	-1	1	1	0	0	1	0	0	1	0
12	0	0	-1	0	1	1	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	1	1	0	0	1	0	0	0	0
15	0	1	-1	0	1	1	0	1	0	0	0
16	0	1	0	0	0	0	0	1	0	0	0
17	0	1	1	1	0	0	1	1	0	0	0
18	1	-1	-1	X	X	1	0	0	0	1	0
19	1	-1	0	1	0	1	0	0	0	1	0
20	1	-1	1	1	0	X	X	0	0	1	0
21	1	0	-1	X	X	1	0	0	0	0	0
22	1	0	0	1	0	1	0	0	0	0	0
23	1	0	1	1	0	X	X	0	0	0	0
24	1	1	-1	X	X	1	0	1	0	0	0
25	1	1	0	1	0	1	0	1	0	0	0
26	1	1	1	1	0	X	X	1	0	0	0



Propulsion Trades - Small Impulse Bit Control (1 of 2)

- Propulsion Options for Stellar Mapping Backup Solar Precession, Nutation Damping Augmentation and Spin Rate Variation Control
 - Current Hydrazine System Cannot Perform These Functions With Current Minimum Impulse Bit Capabilities
- Augment Current Hydrazine System
 - Incorporate Fast Acting 1 N Thruster and Investigate Re-orificing for Smaller Impulse Bit
 - TBD Cost and Schedule
 - Incorporate Separate Tank for Blowdown Pressure Control
 - Lower Operating Pressure for Thrusters During Stellar Mapping
 - Requires Additional Gas Storage Tank
 - Pressure Regulation Options
 - Bang- Bang with Feed Back Control Similar to Clementine
 - Mechanical Regulator
 - Shuttle Solenoid Valves
 - Optimize Blowdown Ratio for High Beginning of Life Thrust and Small Science Collection (End of Life) Impulse Bit



Propulsion Trades - Small Impulse Bit Control (2 of 2)

- Implement a Cold Gas Nitrogen Thruster System
 - Blowdown or Regulated System Options
 - 60 Second Specific Impulse
 - Relatively Inexpensive
 - Good For Low Total Impulse Missions
- Implement a Warm Gas Thruster System
 - Ammonia Propellant System
 - 90 Second Specific Impulse
 - Applicable for Higher Total Impulse Than Cold Gas
 - Somewhat More Complicated Than Cold Gas
 - Component Availability is TBD
- Implement a Pulsed Plasma Thruster System
 - Solid Teflon Propellant
 - Dawgstar (AIAA-00-3256) Has Two Nozzles Firing Simultaneously
 - 13.1 Watts and 500 Seconds Specific Impulse
 - 55 μ N-sec Impulse Bit
- Implement Torque Rod System (Selected - See ADCS SRR Package)



Pulsed Plasma Thruster (PPT)



- PPT is Under Investigation for Active Attitude Control During Science Collection
 - Detailed Requirements Analysis Performed by Tae Lim of ADCS
- Modern Design Currently Flying on EO-1 Satellite
 - New Developments With TIP/NOVA Design heritage (1970 -1980's)
- Teflon Bar Propellant
- Two Opposing Nozzle Configuration
- 5 Throttle Ranges (Impulse Bit/ Pulse)
- TBD Cost >\$1M For the Minimum Three Thruster System
- Mass 4.95 Kg
- Input Power 70W, 28V, 1 Pulse/Sec
- Pulse Frequency up to 1 Hz
- Specific Impulse 650-1400 Seconds
- Impulse Bit 90-860 micro-N-seconds
- Upgrades Required for Use on FAME
 - Fuel Capacity, PMP, Electronics Switching, Program Documentation
 - Qualification Upgrade May be Required



PPT System Investigated for Science ACS

- **Hardware Performance Met Mission Attitude Control Requirements**
- **Science Team Did Not Accept Impulse ACS Methods**
 - **Jitter Concerns Limits System Use to Once Per 10 Minutes**
 - **Science Data Reduction Impacts “Significant”**
- **Investigated Using Modified EO-1 PPT**
 - **Manufactured By General Dynamics (Formerly PRIMEX Aerospace)**
 - **Upgrade Design and Electronics for High Reliability**
 - **Investigate Adding a Third Clustered Nozzle to the Current Two Opposing Nozzle Configuration**
- **Cost and Delivery Concerns for FAME**



Propulsion Component Safety Factors



<u>Factors of Safety</u>	<u>Gnd Ops</u>	<u>Flight Proof</u>	<u>Flight Burst</u>
Propellant Tanks	>1.5	>1.25	>1.5
Helium Tanks	>2.0	1.5	>2.0
Lines	>4.0	4.0	>4.0
Components	>4.0	1.5	>4.0



Component Weights

RCS SUBSYSTEM			162.80	19%	137.25
PROPELLANT, HYDRAZINE	1	x	110.00	25%	88.00
PROPELLANT TANK	1	x	16.80	5%	16.00
PRESSURANT	1	x	0.22	10%	0.20
PRESSURANT TANK	5	x	10.61	5%	10.10
PRESSURANT TANK SUPPORT	1	x	4.40	10%	4.00
THRUSTER, 5 LBM FORCE	2	x	3.15	5%	3.00
THRUSTER, .2 LBM FORCE	6	x	4.73	5%	4.50
PROPELLANT LINE	1	x	4.80	20%	4.00
PROPELLANT LINE CLAMP	45	x	0.54	20%	0.45
PROPELLANT LINE STANDOFF	45	x	0.60	20%	0.50
PROPELLANT FILL VALVE	3	x	0.95	5%	0.90
PRESSURE TRANSDUCER	2	x	1.05	5%	1.00
PRESSURE TRANSDUCER CLAMP	4	x	0.21	5%	0.20
PROPELLANT FILTER	1	x	1.05	5%	1.00
PROPELLANT LATCH VALVE	1	x	1.89	5%	1.80
PYRO ISOLATION VALVE	2	x	0.74	5%	0.70
FILTER BRACKET	2	x	0.19	20%	0.16
FILL VALVE BRACKET	2	x	0.76	20%	0.63
LATCH VALVE BRACKET	2	x	0.13	20%	0.11



Possible Hardware Mass Savings (1 of 2)

- **Mass Saving Options For the Current Mass Limited Design**
 - **Optimize the Pressurization System (See Pressure Trades)**
 - **Fewer Tanks with More Optimal Volumetric Packaging**
 - **Potential Savings 4 lbs**
 - **Implement Multiple Re-Pressurization System**
 - **Adds Valves and Complexity but Can Reduce Volume and Mass**
 - **Potential Savings 4 lbs**
 - **Potential Savings With Optimized Tanks 6 lbs**
 - **Eliminate Pyrotechnic Isolation Valves and Helium Tank Service Valve**
 - **Requires Tank Re-Qualification to Launch With Activated Diaphragm**
 - **Tank Wall Supports Diaphragm Before Activation**
 - **Potential Savings 1.5 lbs Plus Ordnance Drivers**
 - **Eliminate Test Service Valve**
 - **Complicates and Limits Latch Valve Testing**
 - **Hydrazine Tank Pressure Capabilities and Cycle Limits**
 - **Potential Savings 0.5 lb**



Possible Hardware Mass Savings (2 of 2)

- **Eliminate Latch Valve**
 - **Mission Dual Leakage Tolerance**
 - **Complicate Ground Processing (Personnel Limits, Vapor Detection)**
 - **Requires Safety Requirements Interpretation of Critical Hazard**
 - **CLEMENTINE Flew This Design**
 - **Potential Savings 2 lbs**
- **Limit Temperature Telemetry Points**
 - **Less Flight Data for Operational Verification and Performance Prediction**
 - **Potential Savings 0.5 lbs Plus Signal Conditioning**



Propellant Margin Games

- Current Hydrazine Propellant Design
 - ACS Budget Based on 1 Sigma (Expected) Vehicle Mass Properties and Flight Operations
 - Delta V Budget Based on 3 Sigma (Worst Case) Vehicle Mass Properties
 - Maximum SRM Propellant Based on Launch Vehicle Throw Capability
 - Highest Pointing and Impulse Error
 - Delta Probability of Command Shut Down (PCS)
 - Overall Margin Applied to Sum of ACS and Delta V Budgets
 - No Double Bookkeeping of Margins
- New Effort to Allocate Propellant Margins to Program Margin Reservse for Bookkeeping Purposes
 - Call 1 Sigma Deviation Contingency
 - Bookkeep the Difference Between 3 and 1 Sigma Performance As Margin
 - Transforms 6 Kg to System Margin
 - Perform Error Averaging Rather Than Summation
 - Provides Additional System Margin
 - Transforms 4 Kg to System Margin



ACS Propellant Budget

	Configuration	Mprop (kg)	Mprop (lbm)
1	Flight Vehicle, Wet AKM	8.9	19.7
2	Flight Vehicle, Dry AKM	7.0	15.3
3	Spacecraft (post-AKM jettison)	2.2	4.8
		total	18.1
			39.9

1	Flight Vehicle, Wet AKM		
	Null tip-off from Delta 3rd stage	0.10	
	Inertial pointing (3-axis limit cycle)	0.14	
	Slew maneuvers	0.40	
	SHM spin-up/down	0.06	
	Inertial ptg during ACS Delta-V	0.06	
	AKM spin-up	1.36	
	Active Nutation Control *	6.52	
	Spin axis precession	0.27	
	subtotal	8.9	kg

2	Flight Vehicle, Dry AKM		
	ANC following AKM firing	1.84	
	Post-AKM spin-down	1.11	
	Slew maneuvers	0.58	
	Inertial ptg during ACS Delta-V	0.07	
	Inertial pointing (3-axis limit cycle)	3.37	
	subtotal	7.0	kg

3	Spacecraft (post-Interstage separation)		
	Slew maneuvers	0.27	
	Inertial pointing (3-axis limit cycle)	1.07	
	Inertial ptg during ACS Delta-V	0.15	
	SHM spin-up/down	0.71	
	subtotal	2.2	kg

* Includes 1 hr @ 60rpm, 20 min@20rpm, and ANC during spin-up (25 minutes from 0 to 60rpm)



AKM Pointing Requirements

- **AKM Pointing Errors Result in Altitude and Inclination Errors**
 - **Inclination Errors Were Generally Acceptable for All Worst Case Pointing Cases**
 - **No Correction Required**
- **Worst Case Altitude Error Result In Hydrazine Fuel Requirements**
 - **Some Pointing Errors Exceed Hydrazine Capacity of the Small Metal Diaphragm Tank Design**
 - **Required Bounding Pointing Error to 2°**
 - **AKM Impulse Performance Error Also Considered**
- **ACS Worked With “Worst Case” Numbers for STAR Motor Performance to Verify Acceptable Pointing Performance Will Be Achievable (Requirement: < 2.0 Deg Error)**
- **ACS Calculations Based on Worst-case AKM Misalignments Are Shown to Yield Acceptably Small Pointing Error at 60 Rpm Spin Rate (RSS of Pointing Error and Attitude Determination Error < 2.0 Deg)**
- **Spin Rate Required Is 60 Rpm [TBR]**



STAR™ 30 Motor



- **AKM on 3000-lb class telecommunications satellites**
 - Hughes - HS 376
 - Lockheed Martin (RCA/GE/MM) - Series 3000
 - Matra Marconi (BAe) - Skynet
 - CTA/OSC - Indostar
- **Qualified to a variety of launch environments**
 - Delta, Ariane, Atlas, Long March 3, Shuttle, Titan, H-1
- **Thrust Alignment**
 - **Thrust Axis Perpendicular To Motor Attachment Plane ≤ 0.001 radian**
 - **Thrust Axis Radial Displacement From SRM C/L ≤ 0.01 in**
- **Safety**
 - Toroidal Igniter
 - Model 2134B Safe/Arm Device



Versions of the STAR™ 30 Motor



STAR™ 30BP



Hughes
Matra Marconi
Space
Lockheed Martin

Y0491214B
[309]

**STAR™
30C/CBP**



Hughes
Lockheed Martin

STAR™ 30E



Matra Marconi
Space
Lockheed Martin
Orbital Sciences



STAR™ 30 Motor Tests and Flights



Static Tests

STAR 30/30A (1974 to 1977)	4
STAR 30B (1979 to 1987)	14
STAR 30BP (1984 to 1986, 1989)	5
STAR 30C (1983 to 1985)	4
STAR 30E (1985)	3
Total	30

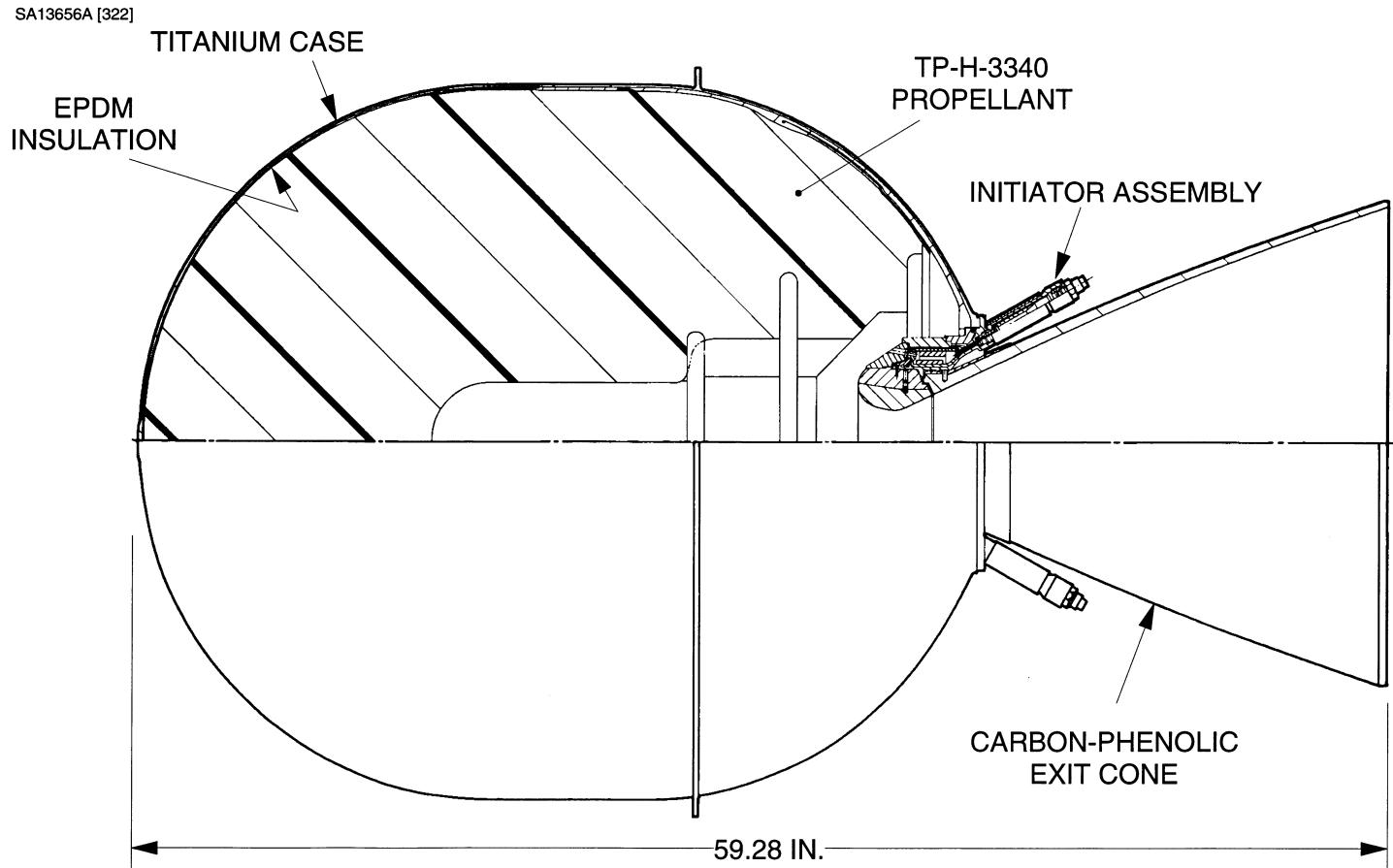
Flights - 100% Success Rate

	Opportunities	Successes	No-Tests
STAR 30B (1980 to 1988)	30	29	1
STAR 30BP (1984 to present)	24	23	1
STAR 30C (1985 to present)	25	22	3
STAR 30E (1988 to present)	10	10	0
Total	89	84	5

V0994511B [196]



STAR™ 30BP (TE-M-700-20) Rocket Motor Assembly





STAR™ 30 Motor Mass Properties and Performance Summary

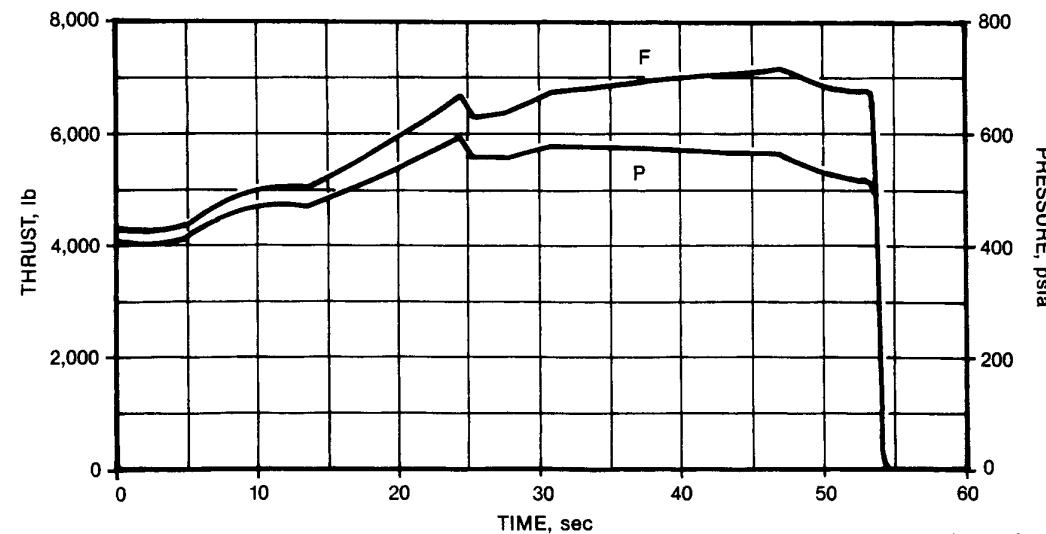
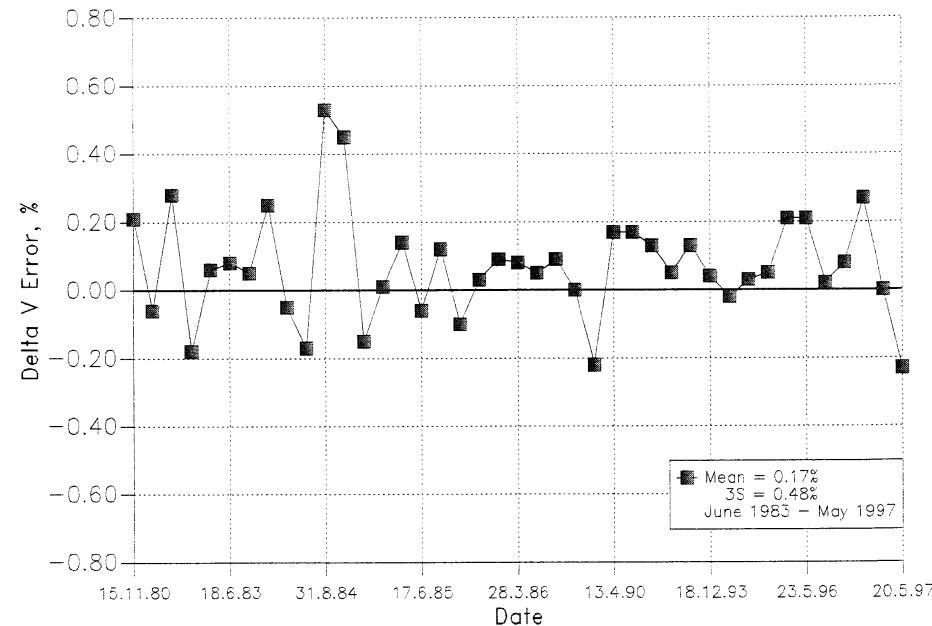


	STAR 30BP	STAR 30C	STAR 30C/BP	STAR 30E
Length, in.	59	59	64	66
Diameter, in.	30	30	30	30
Weights, lbm				
Loaded motor	1,197	1,389	1,393	1,486
Propellant	1,114	1,302	1,302	1,392
Burnout	72	74	80	82
Total impulse, lbf-sec	328,455	376,095	383,220	407,550
Effective Isp, sec	292.3	286.4	291.8	290.4



STAR™ 30 Performance

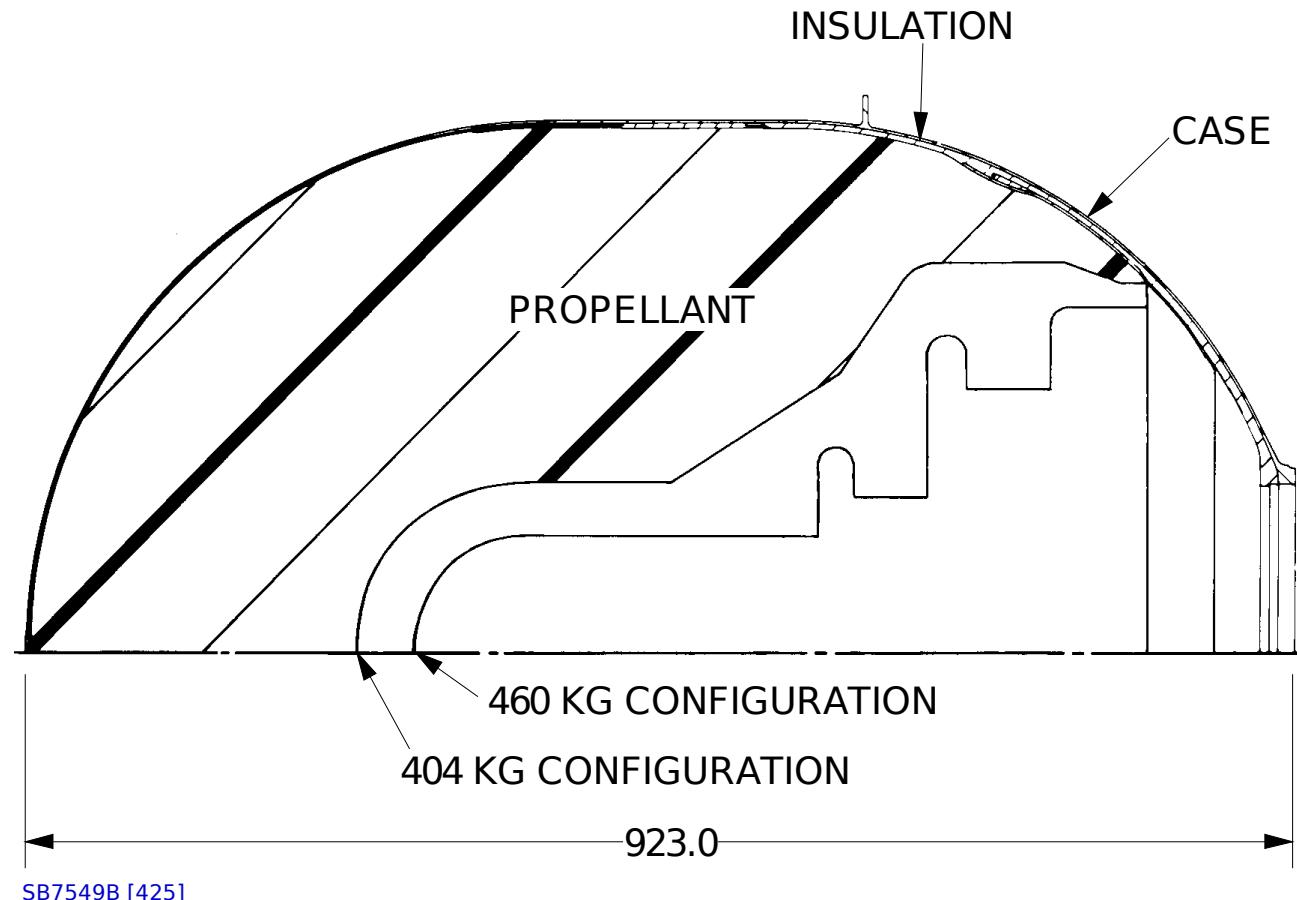
- Based Upon 1993 Hughes Data for ΔV Error for All STAR™ 30 Flights to That Date
 - Mean - 0.07%
 - RMS - 0.17%
 - Standard Deviation - 0.16%



thrust_performance.tif



STAR™ 30BP Loaded Motor Case: Propellant Off-Loading Example





Thiokol Propulsion/Elkton Off-Loading History



STAR™ Motor	Full-Load Propellant Wt, lb_m	Maximum Off-Load Propellant Wt, lb_m	Off-Loads Flown Without Static Tests, lb_m	Off-Loads Static Tested, lb_m
27	735	675 (8.2%)	-	675 (8.2%) 690 700 703 709
30BP	1113	892 (19.9%)	910 (18.2%) 927 939 1001 1014 1043 1044 1065 1070 1075 1079 1089 1097 1099 1103	892 (19.9%) 1040 1080

Y791088A (1) [014]



Thiokol Propulsion/Elkton Off-Loading History

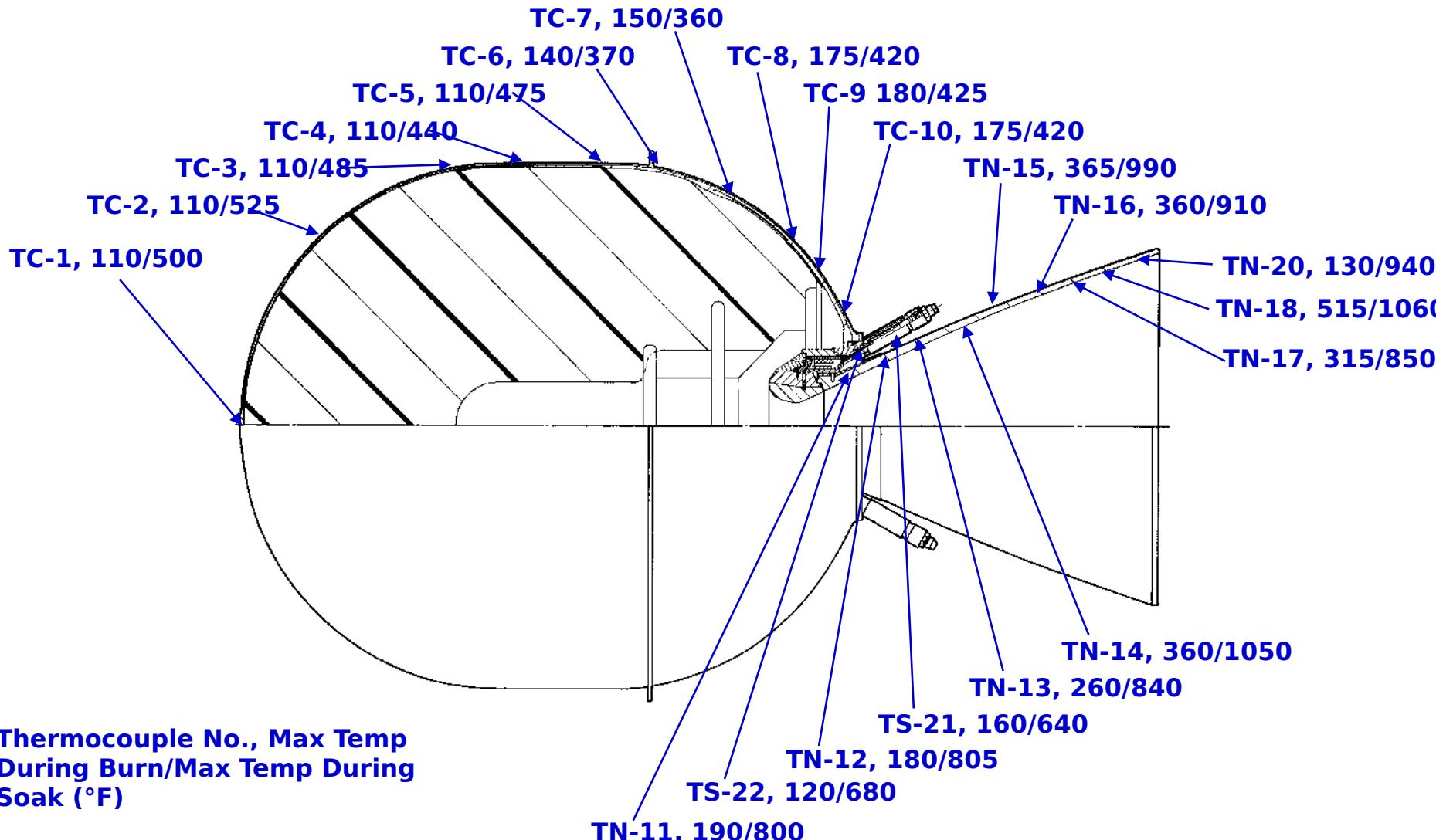


STAR™ Motor	Full-Load Propellant Wt, lb _m	Maximum Off-Load Propellant Wt, lb _m	Off-Loads Flown Without Static Tests, lb _m	Off-Loads Static Tested, lb _m
30C	1302	1032 (21%)	1101 (15.4%) 1118 1137 1168	1032 (21%)
30E	1392	1235 (11.3%)	1367 1370 1380 1384	1235 (11.3%) 1380 (0.9%)
37XFP	1948	1570 (19.4%)	1580 (18.9%) 1667 1715 1763 1922	1570 (19.8%) 1605 1797 1922
37FM	2350	2009 (14.5%)	2009 (14.5%) 2292	2228 (5.2%) 2260 2332
48B	4430	3833 (13.5%)	4300	3833 (13.5%) 4405

Y791088A (2) [014]



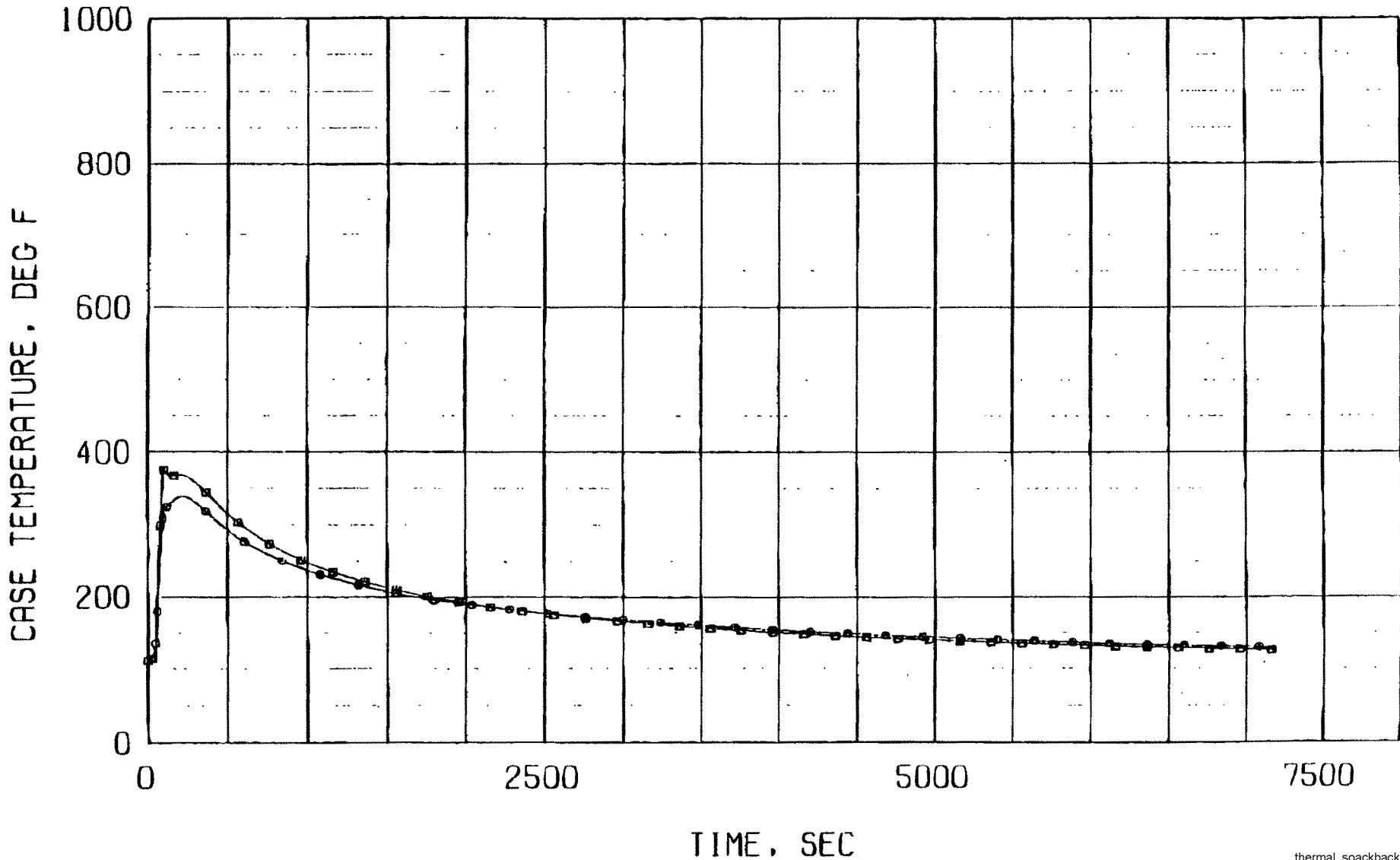
STAR 30BP Temperature Profile



Maximum Measured Motor Case Temperatures



STAR 30BP Thermal Soakback



TC-6 Data, Case Temperature at Mounting Flange

thermal_soakback.tif



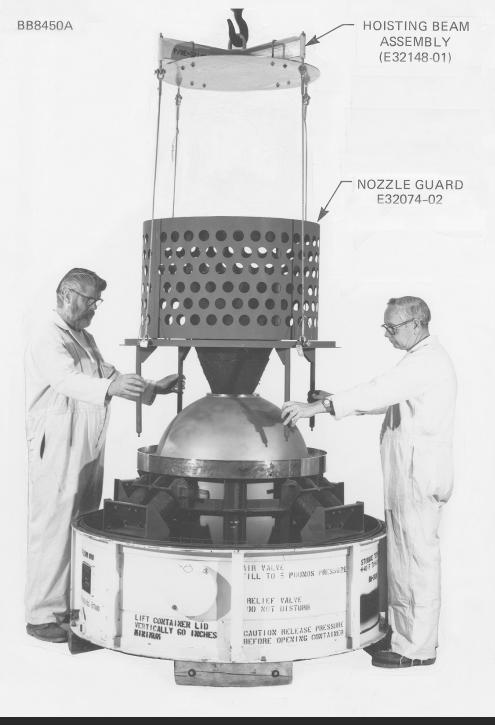
STAR 30BP Integration & Test



P980207/043



**Shipping Container Base
Nozzle Plug Fixture
Pressure Test Equipment**



**Motor Stand
Finger Fixture**



**Lift Fixture
Nozzle Guard
Handling Ring**

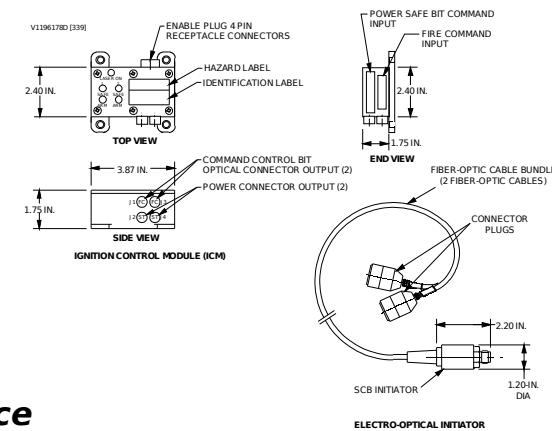


Safe-and-Arm Comparison

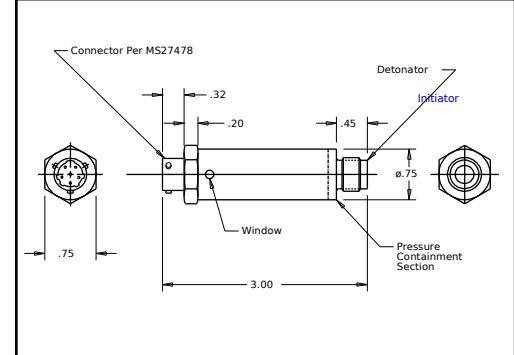
Conventional Electromechanical



Electro-Optical



All-Electronic



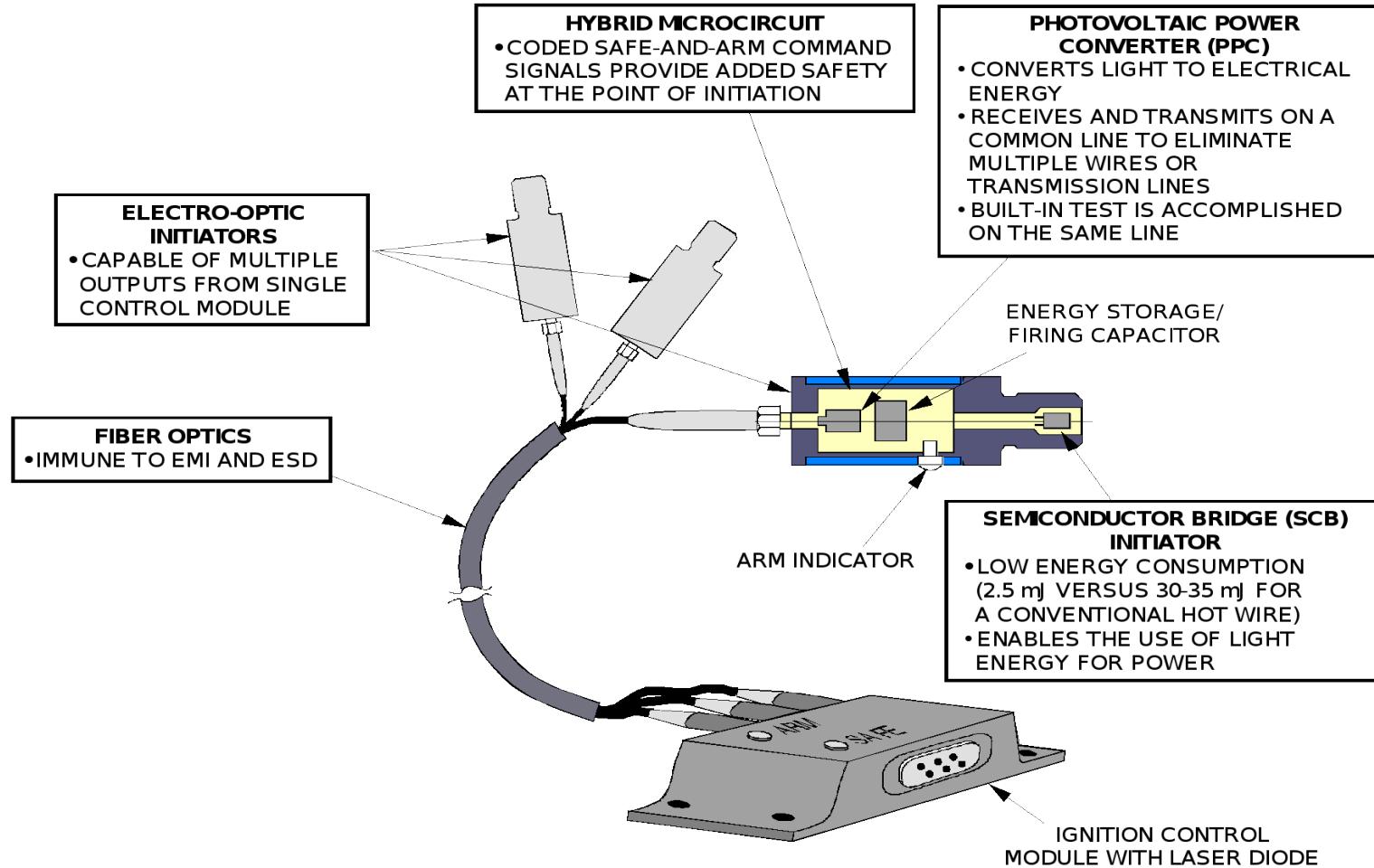
Model 2134B Safe-and-Arm Device

Characteristics	2134B System	EOSA System	ESA System	
Weight, lb	S&A (1) ETAs (2) TBIs (2) Total -	3.50 0.88 0.21 4.59	ICM (1) 1.25 Optic cables (2) 0.64 Initiators (2) <u>0.40</u> Total - 2.29	Initiators (2) Cables (2) Total - 0.30 0.20 0.50
Envelope, in. ³	60	30	1.5	
Explosive content	All components contain explosives	Inert except for the electro-optical initiator on the motor	All components contain explosives and are shielded	
Events controlled	Motor initiation (redundant output to initiate two ETAs)	Multiple events or just motor initiation (using a redundant output) - depending upon the planned application	Various - system requires coded signal to function	

V1196140B [340]



Electro-Optical Safe-and-Arm Concept

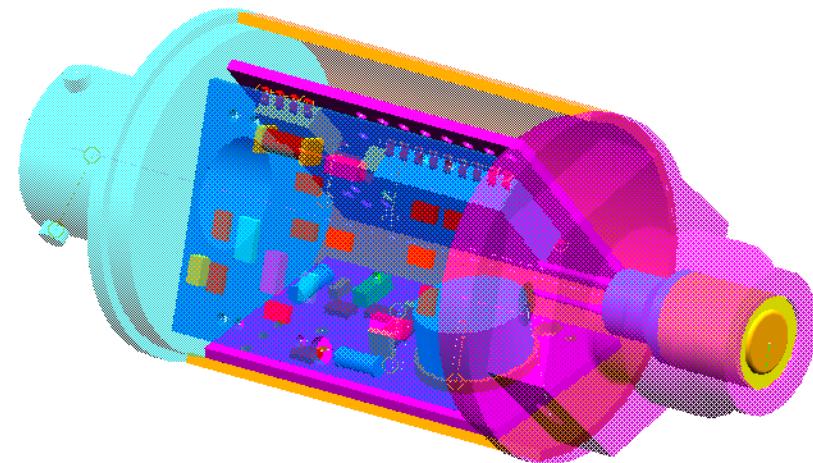


V0394245E [155]



ESA

- All operations powered by arming signal input
- Internal bridge verification
- Integral microcontroller
- Low power requirements
- Low-energy semiconductor bridge (SCB)
- Discharge capacitor power level monitor
- Quick-safing feature
- Low pin count



V0599011 [428]



ESA Specification

- **Electrical signal specifications**
 - **Input signals consist of an Arm and Fire**
 - **Arm signal input 18-36 VDC**
 - **Max 50 mA steady-state and max 250 mA transient current**
 - **Arm time < 100 msec**
 - **Fire signal input 12-36 VDC**
 - **Max 10 mA steady-state and transient current**
 - **Fire output time <10msec**
 - **Microcontroller control system**
 - **Microcontroller power supply energy received from arm input signal. ESA is unpowered in unarmed state**
 - **Arm and Fire signals are electronically sensed for signal level and bandwidth to guarantee signal integrity**
 - **Squib verification circuitry prior to arming capacitor**
 - **Separate fire capacitor arm input switch after microcontroller arm signal verification**



ESA Specification (Continued)

- **Electrical signal specifications (continued)**
 - **Dual capacitive discharge fire switched for squib isolation and non-single point failure control**
 - **Fire input is immediately processed through microcontroller interrupt**
 - **Electrical initiation of explosive powder is accomplished by semiconductor bridge (SCB)**
 - **SCB initiator is electrically isolated from ESA input signals and current limited from ground prior to fire output**

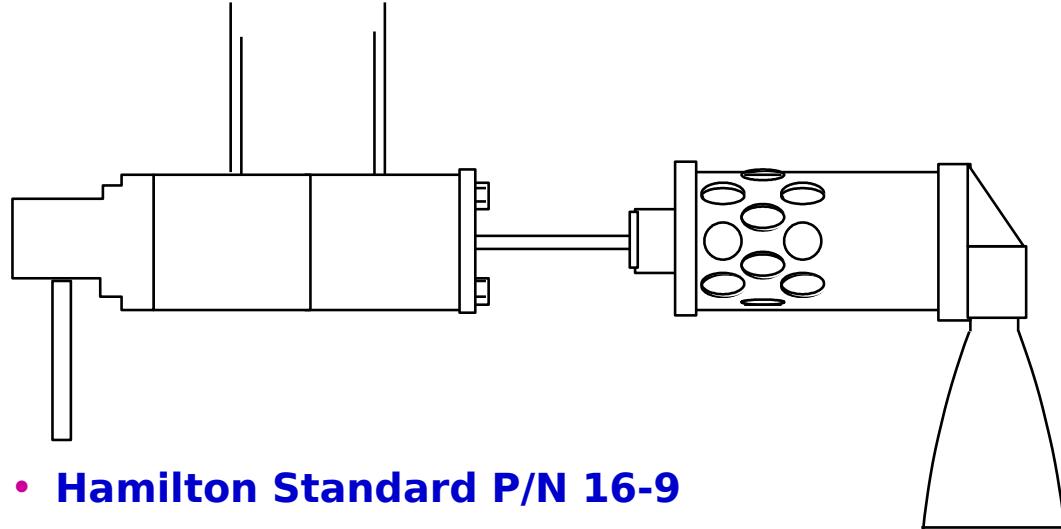


ESA Specification (Continued)

- **Output characteristics**
 - Charge material is 88 mg of TSPP
 - Core SCB initiator
 - Initiator function time: \approx 50 μ sec
 - Core SCB initiator tested to MIL-STD-1512
- **Physical characteristics**
 - Overall length 2.5 in.
 - Overall diameter 1.0 in.
 - Installed length 2.0 in.
 - Material construction 304L stainless steel
 - Weight 0.172 lb
 - Hermetic seal



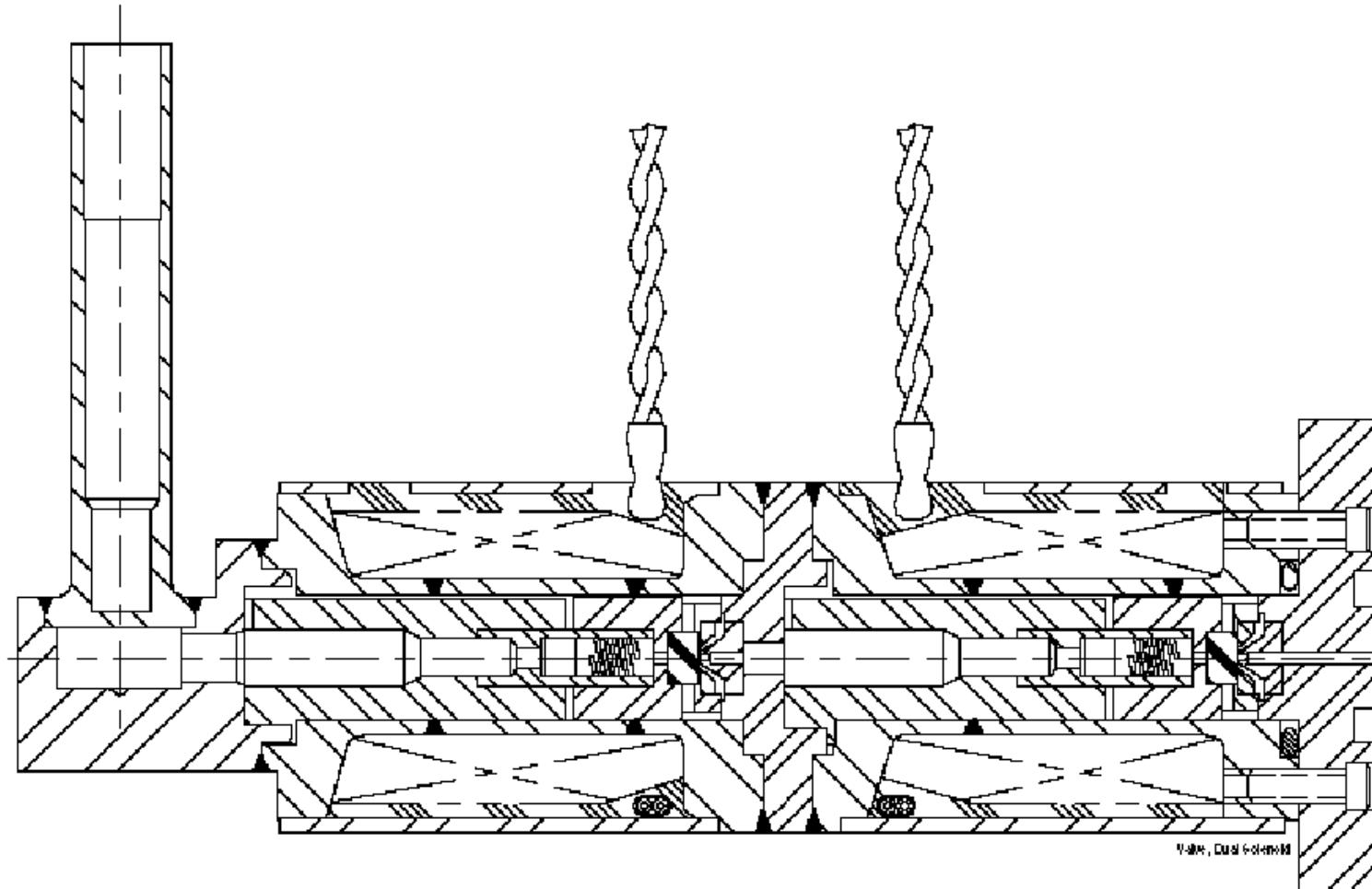
5.0 Lbf Thruster



- **Hamilton Standard P/N 16-9**
- **Thrust 5.0 - 2.10 lbf, Isp 220 Lbf•s**
- **Assembly Weight 1.65 lb, 0.70 lb Max Valve Only**
- **Feed Pressure: 320 - 106 psia**
- **Qualification NTS II, Status: In-House**
- **Valve ValveTech, Inc P/N 15059**
- **40 to 122 F 20 to 140 F Qual**
- **Internal Leakage 5.0×10^{-6} scc/sec He**
- **External Leakage 1.0×10^{-6} scc/sec He**
- **22 to 36 VDC, 75 Ohms Each Coil**
- **500,000 cycles, 15 ms Response Maximum (-24 VDC Suppression)**
- **0 to 350 psig, 700 psig Proof, 1400 psig Burst**



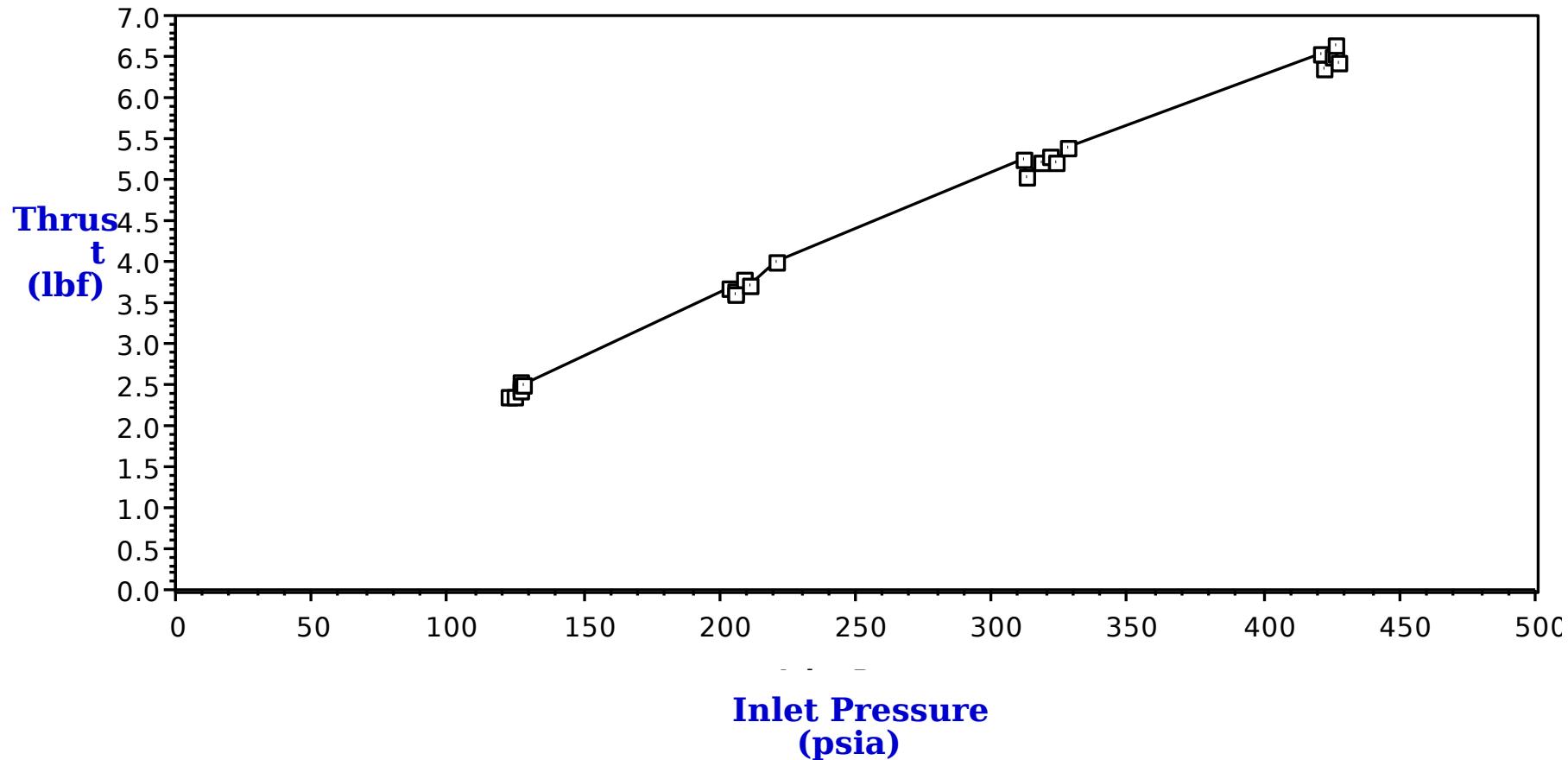
5.0 lb Dual Seat Thruster Valve





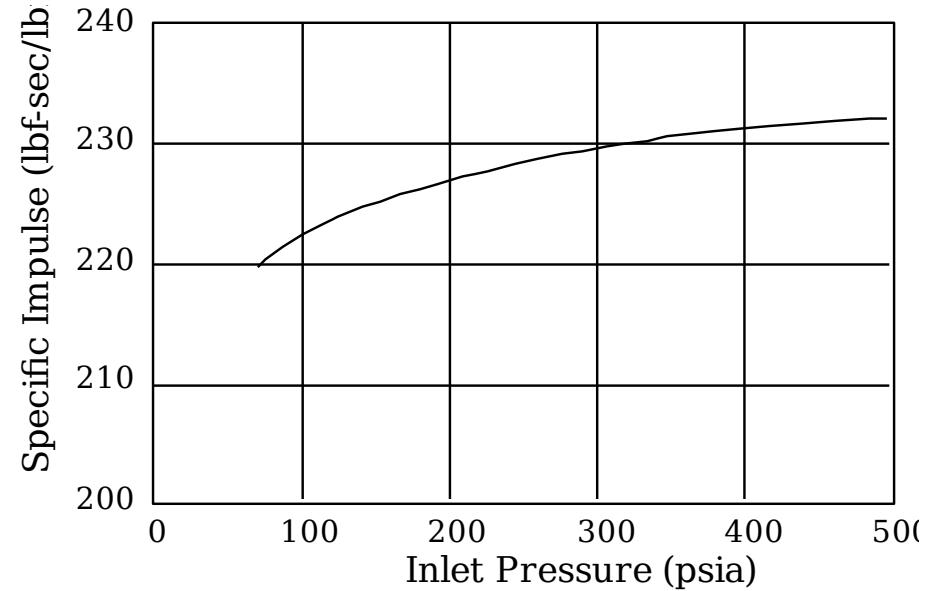
5 Lb Thruster Performance Curves (1 of 2)

REA 16-9 ATP DATA





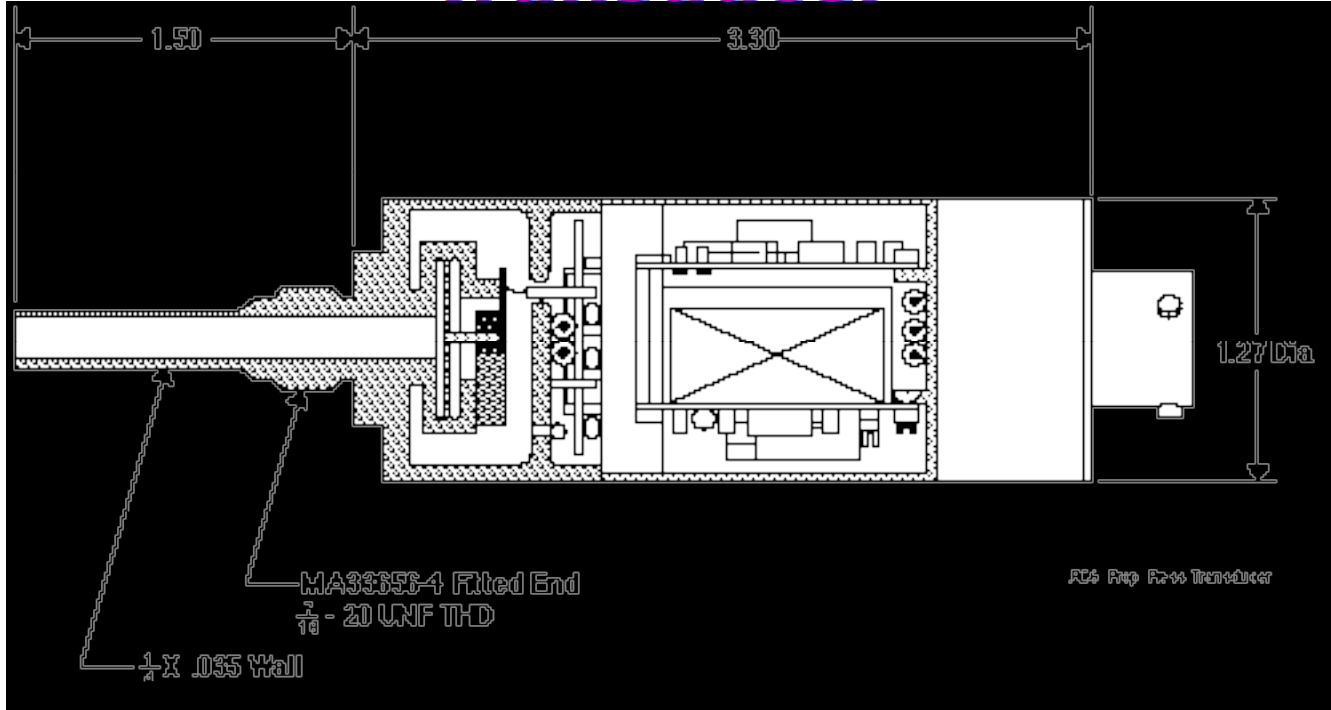
5 Lb Thruster Performance Curves (2 of 2)



PROP-29



Propellant Pressure Transducer



Characteristics

- Model PA4089, Thin Film Deposited Strain Gauges
- Operating Pressure 0-500 psia
- Pressure Sensor: Deflecting Beam, 17-4-PH, Double Sealed
- Electron Beam Welding
- Hermetically Sealed Electronics Package 22-36 VDC Input < 15 mA @ 28 VDC 5 VDC Output
- Status: In- House

Manufacturer

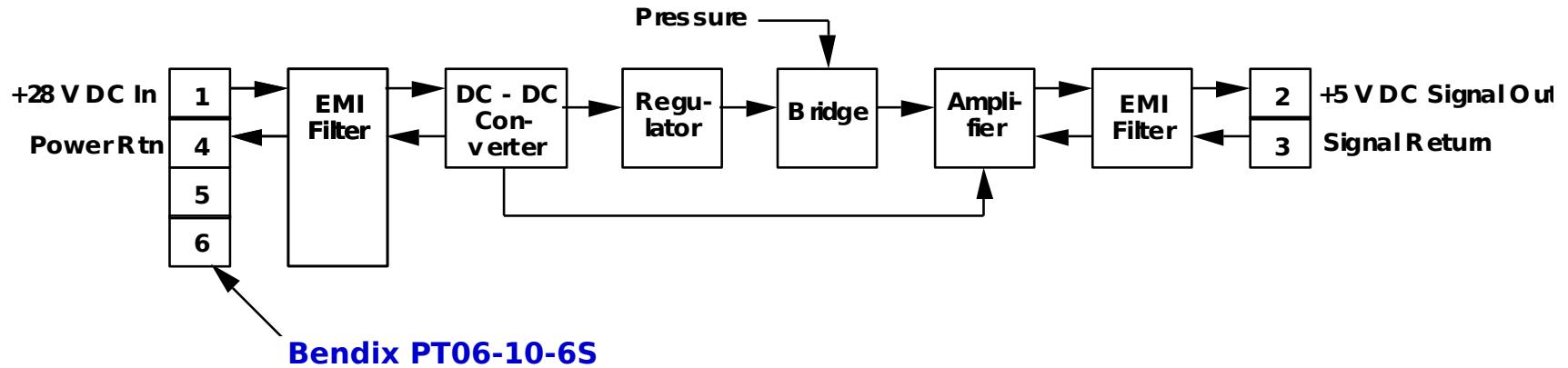
Mark IV, Statham
Oxnard, CA
P/N: PA4089

Qualification

SSD-TP-SD026

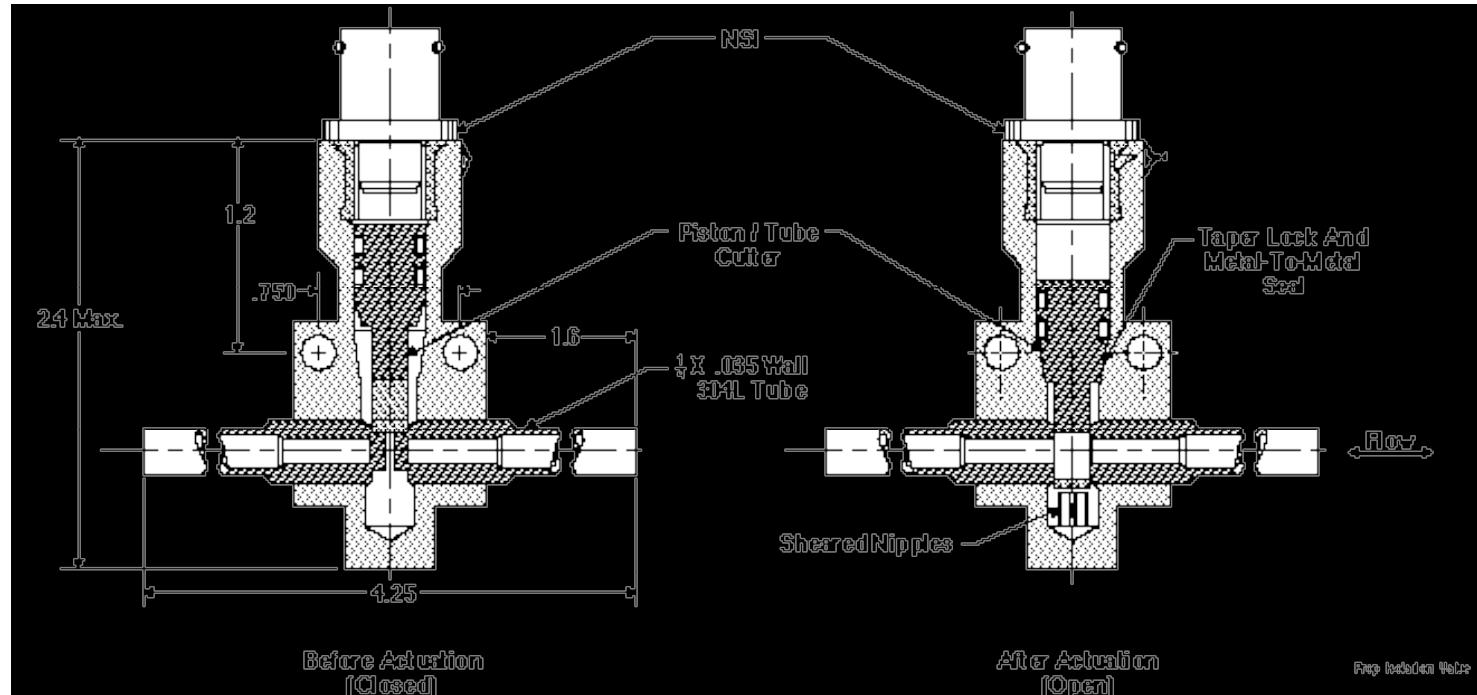


Transducer Block Diagram





Pressurant Isolation Valve

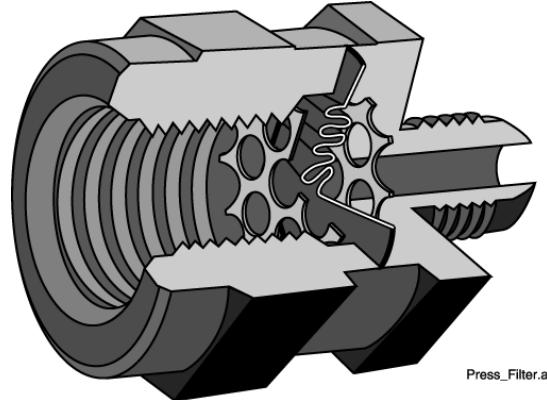


Characteristics Manufacturer

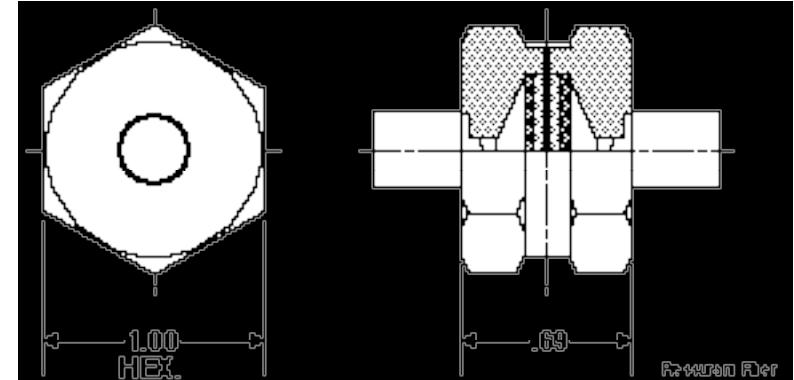
- Pyrotechnically Operated Guillotine Valve
 - Pressures: 4,200 psig Operating
8,000 psig Proof
16,000 psig Burst
 - Leakage: < 1 x 10-6 SCC/s He @ 4,000 psig Qualification
 - Weight: 0.30 lb
 - Flow Rate: 11 SCFM He @ 150 psid Minimum, Either Direction
 - NSI's GFE Status: In-House
- Pyronetic Devices Inc.
Denver, CO
P/N: 1430-22 N/C
- SSD-TR-SD003
OEA 9-1430-22 Rev A



Optional Helium Filter



Press_Filter.ai



Newton Filter

Helium Filter Under Trade for Incorporation into Flight Pressure System May be Used As Remove Before Flight Ground Support Equipment

Characteristics

- 300 Series SS, All Weld Construction
- Pleated Filtration Element, 1.90 in²
- 10 μ Absolute
- Weight: 0.16 lb 4T4T
- Pressures: 6,000 psig Operating
9,000 psig Proof
12,000 psig Burst
- Capable Of Hard Slam Activation/Recovery

Status: In-House

Manufacturer

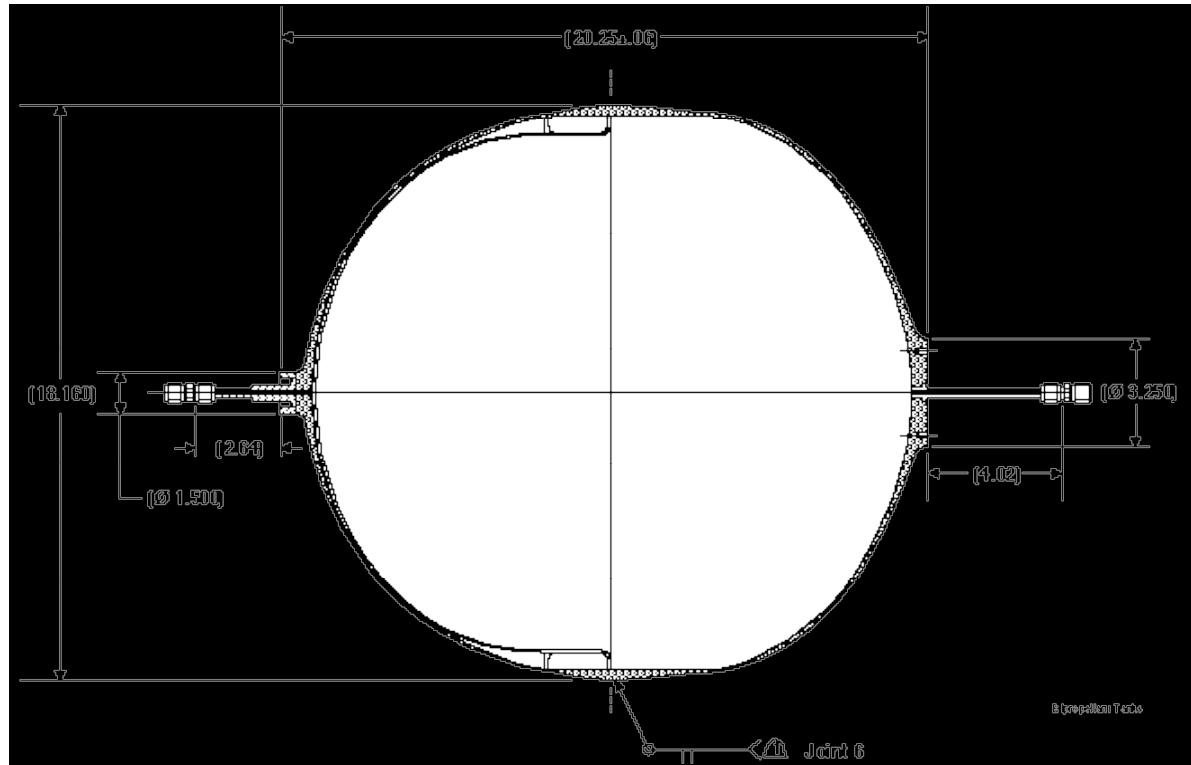
**Brunswick Defense
Winter Aerospace
Costa Mesa, CA
P/N: F-16C010-**

Qualification

Brunswick



Tanks



Characteristics

- OD: 20.6" X 18.2"
- Corporation
- Volume: 3,100 cubic ins Expellable
- Leakage: < 1 x 10⁻⁶ SCC/s @ 50 psig He
- Material: 2219 Aluminum Shell
- 1100 Aluminum Diaphragm
- Pressure: 325 psig Operating
- 650 psig Burst
- Weight: 17.0 lb Max

Manufacturer

Atlantic Research

Niagara Falls, NY

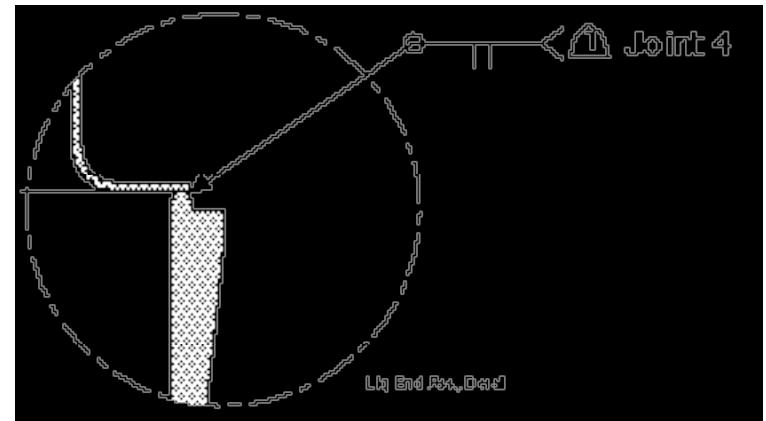
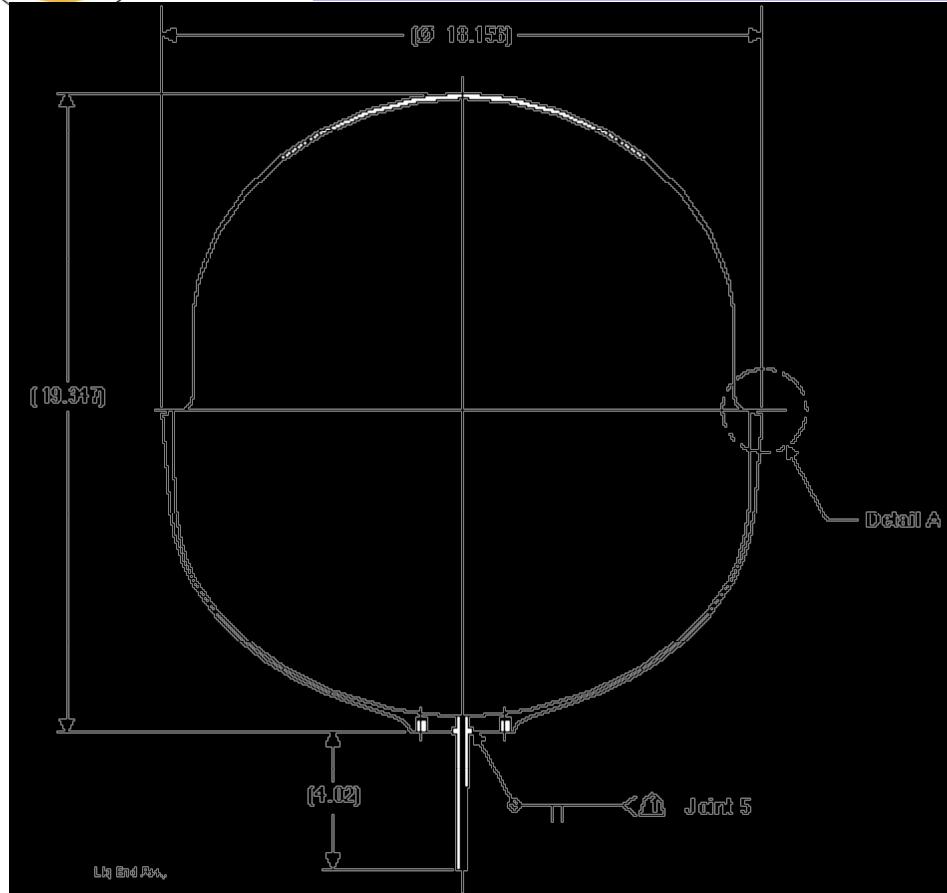
Qualification

ARC

Status: Dec 2002 Delivery



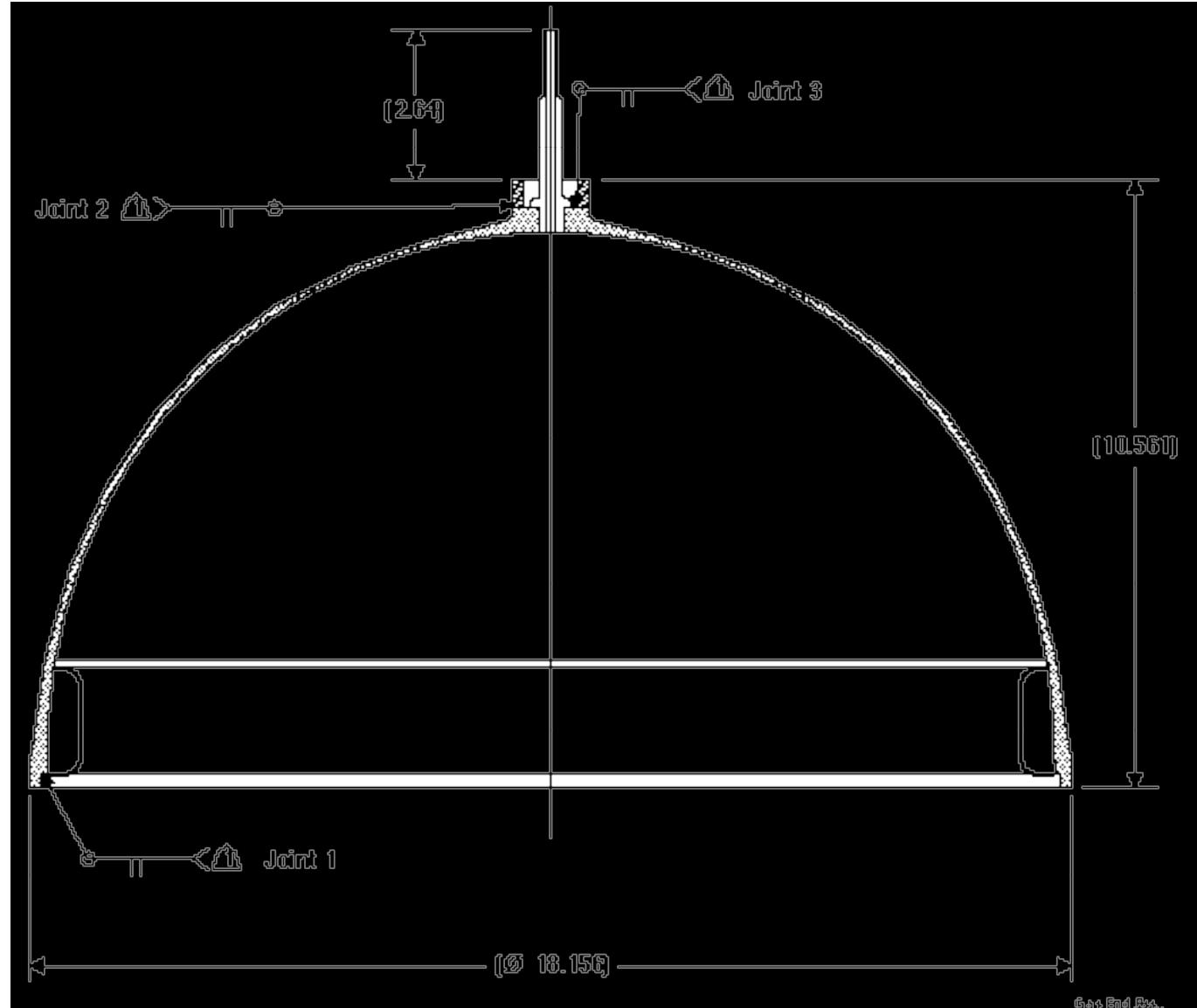
Liquid End Assembly



1. EB Weld Per PP-80535, Addendum 9
2. Mark PN & SN Per PP-80503, Type 4 (Tagging)
3. Package Per PP-80501
4. Clean All Detail Parts Prior To Welding Per PP-80504, Type 14
5. Leak Test At $50 +2/-0$ psig GHe With Diaphragm (F/N 3) Restrained All Around; No Leakage Greater Than 10-6 SCC/SEC

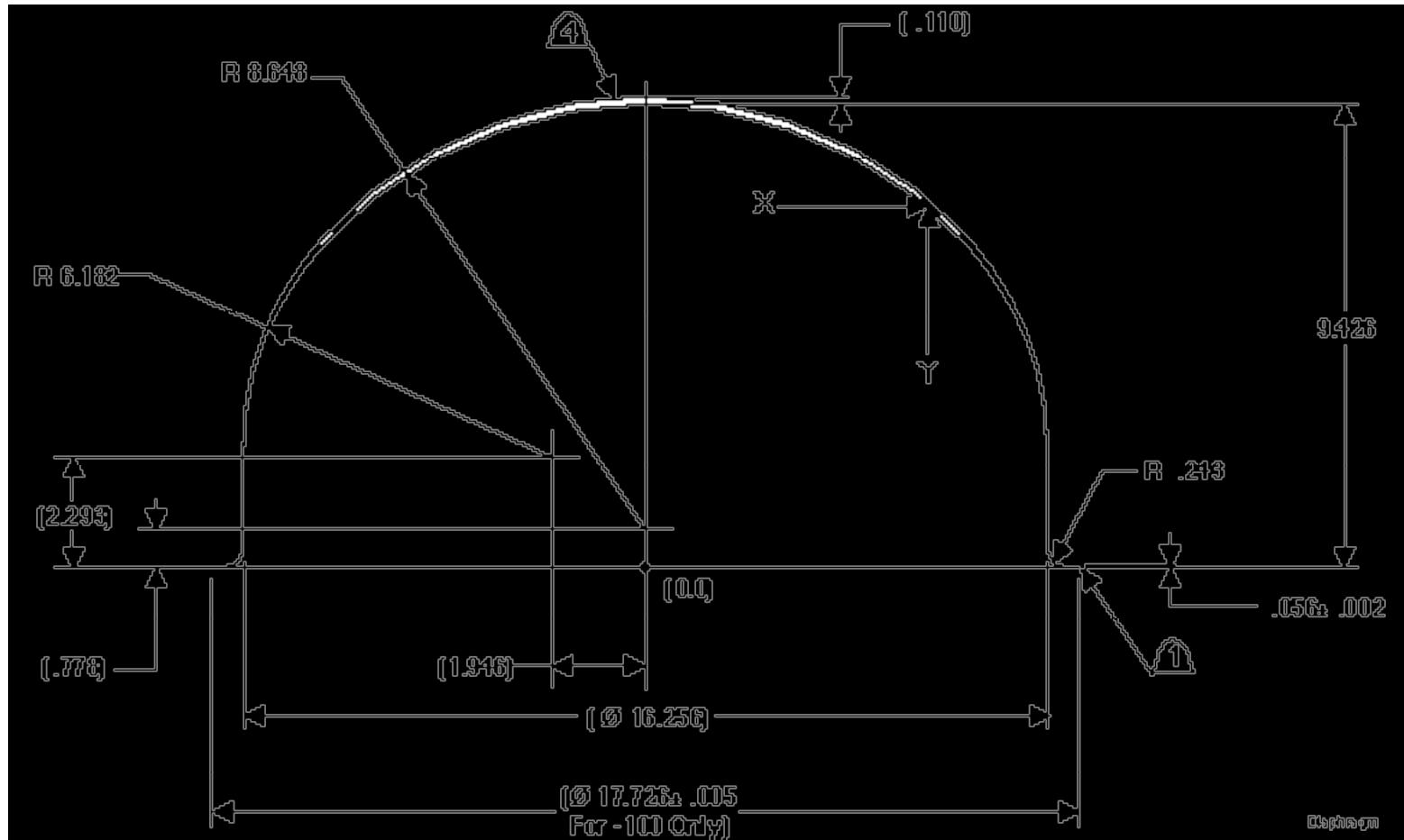


Gas End Assembly



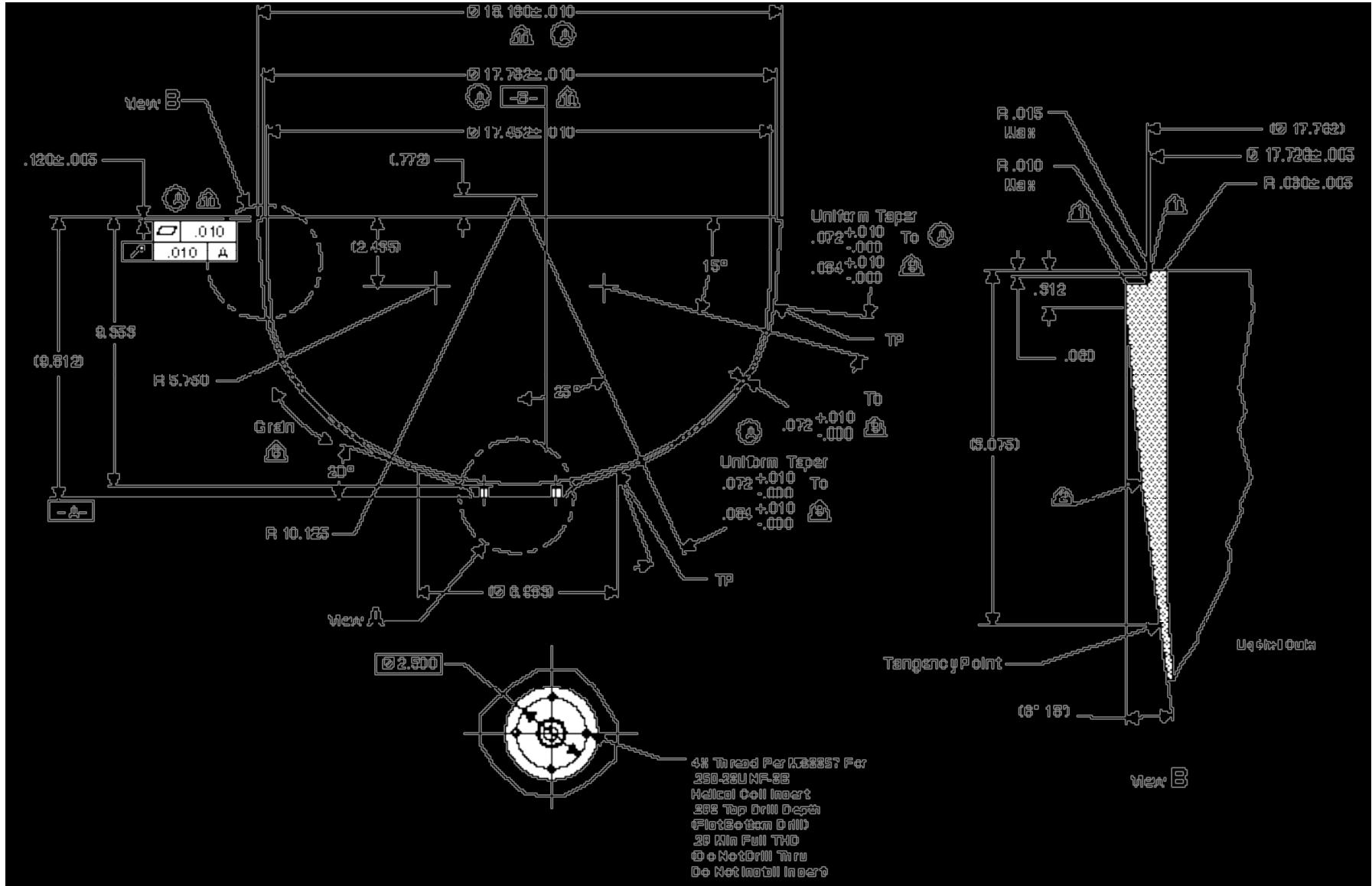


Diaphragm



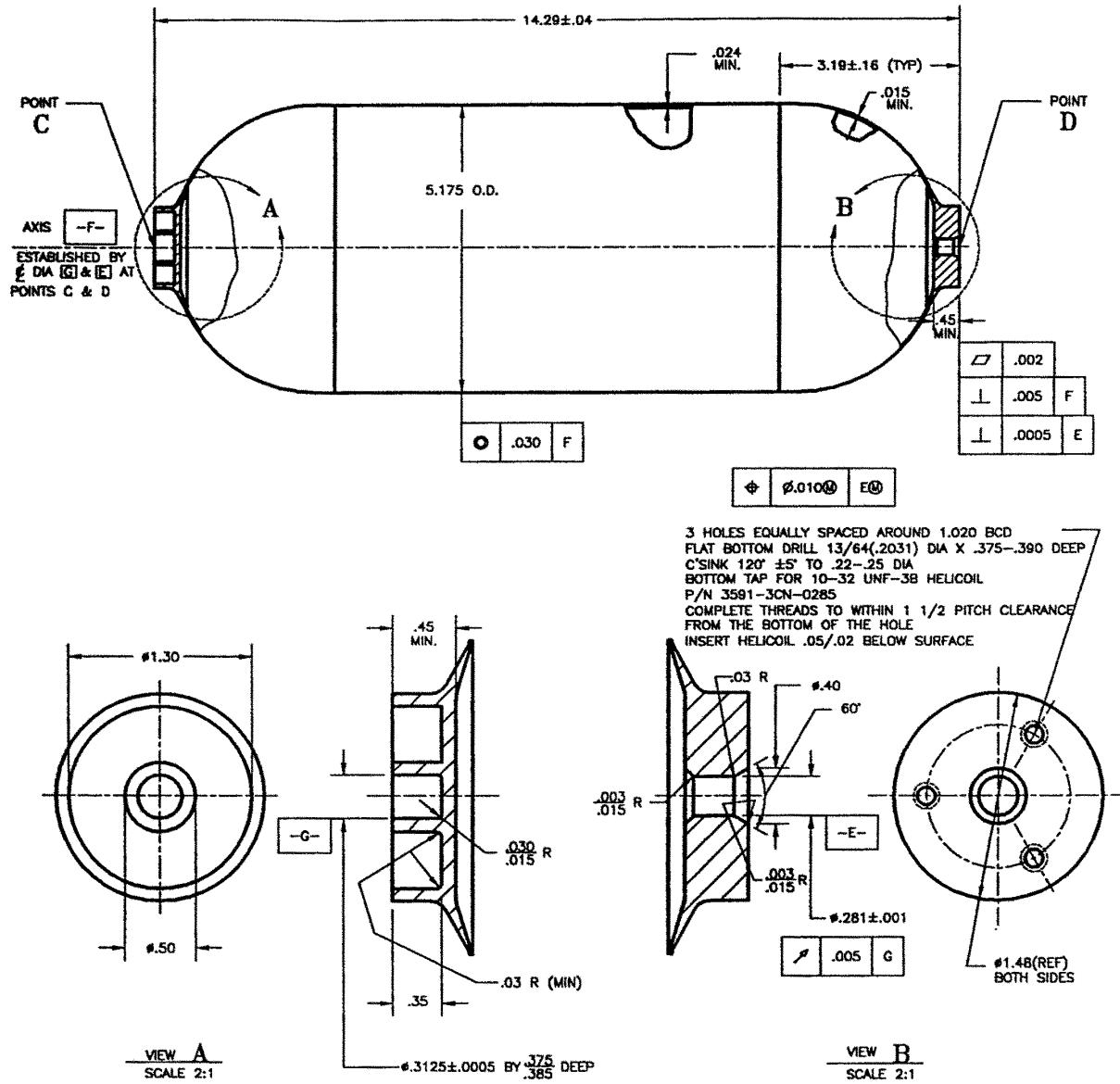


Liquid Shell Outlet



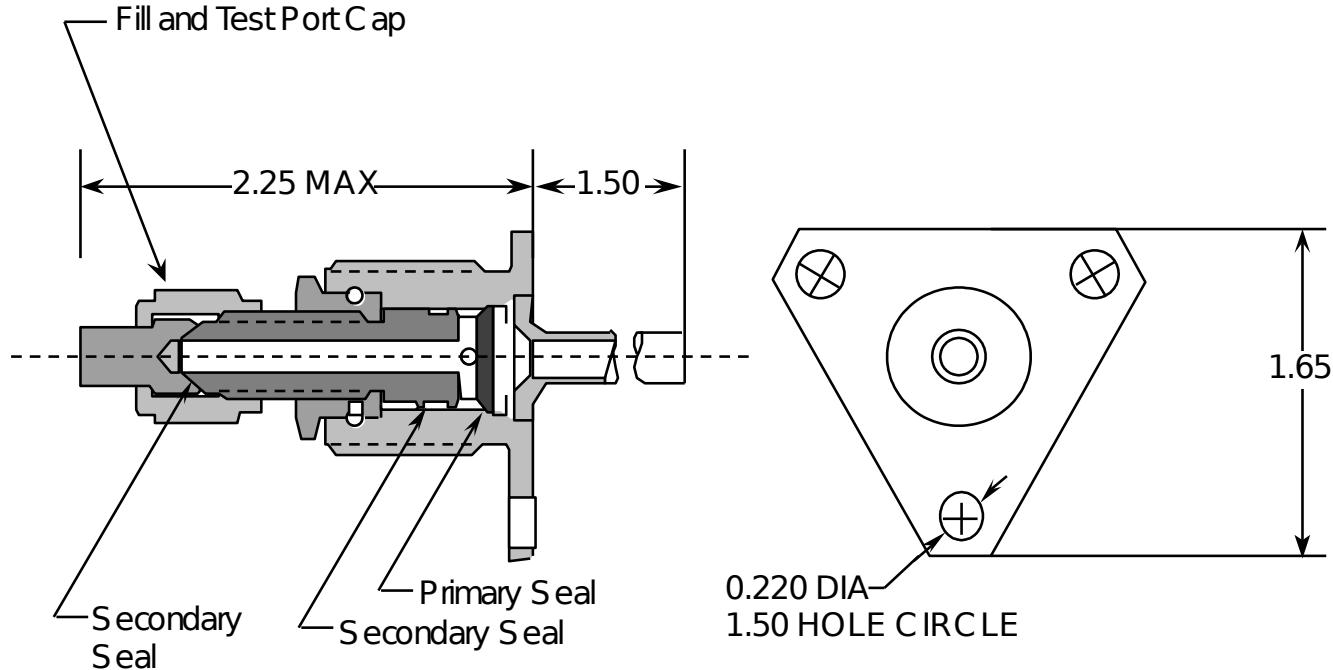


Helium Pressure Tank





Service Valve



Characteristics

- Manually Operated 0.250 in Valve Inc.
- Metal To Metal Seal
- Pressures: 4,000 psig Operating
8,000 psig Proof
16,000 psig Burst
- Leakage: $< 1 \times 10^{-6}$ SCC/s He @ 4,000 psig
- Weight: 0.3 lb max
- Life: > 100 Cycles Minimum
- Shutoff Torque: 30 in lbf
- Single Fault Tolerance Dual Static Seals

Manufacturer

Pyronetic Devices

Denver, CO
P/N: 1831-89

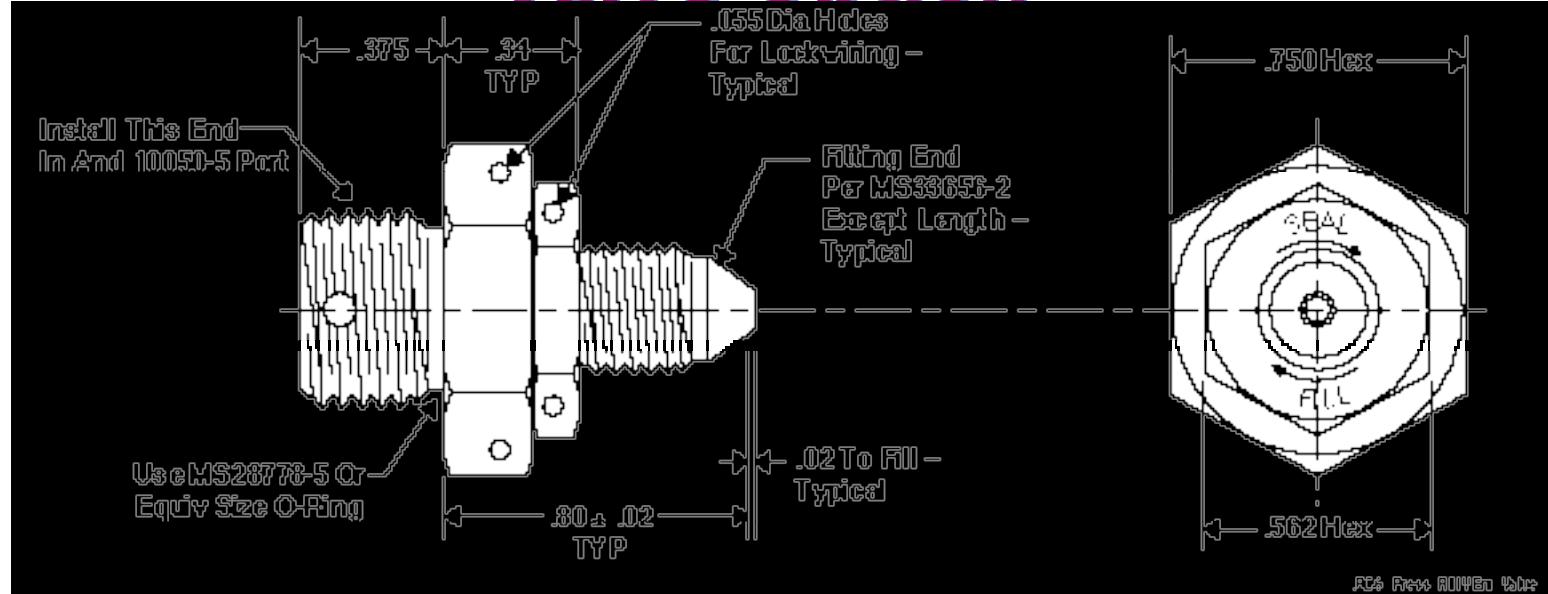
Qualification

SSD-TR-SD002

Status: In-House



Optional Helium Service Valve Option



**Valve is Back-Up Option For Helium Pressurization System
EWR Requirement for Different Valves
Has Single O-Ring Seal (Not Optimal for Helium Permeation
or System Reliability)**

Characteristics

- Manually Operated 0.125 in Valve
- Metal To Metal Seal
- Pressures: 6000 psig Operating
9000 psig Proof
12000 psig Burst
- Leakage: $< 1 \times 10^{-6}$ SCC/s He @ 3,000 psig
- Weight: 0.06 lb
11
- Life: > 100 Cycles
- Material: 304 SS

Manufacturer

Pyronetic Devices Inc.
Denver, CO
P/N: 1819-6 (NRL Mod)

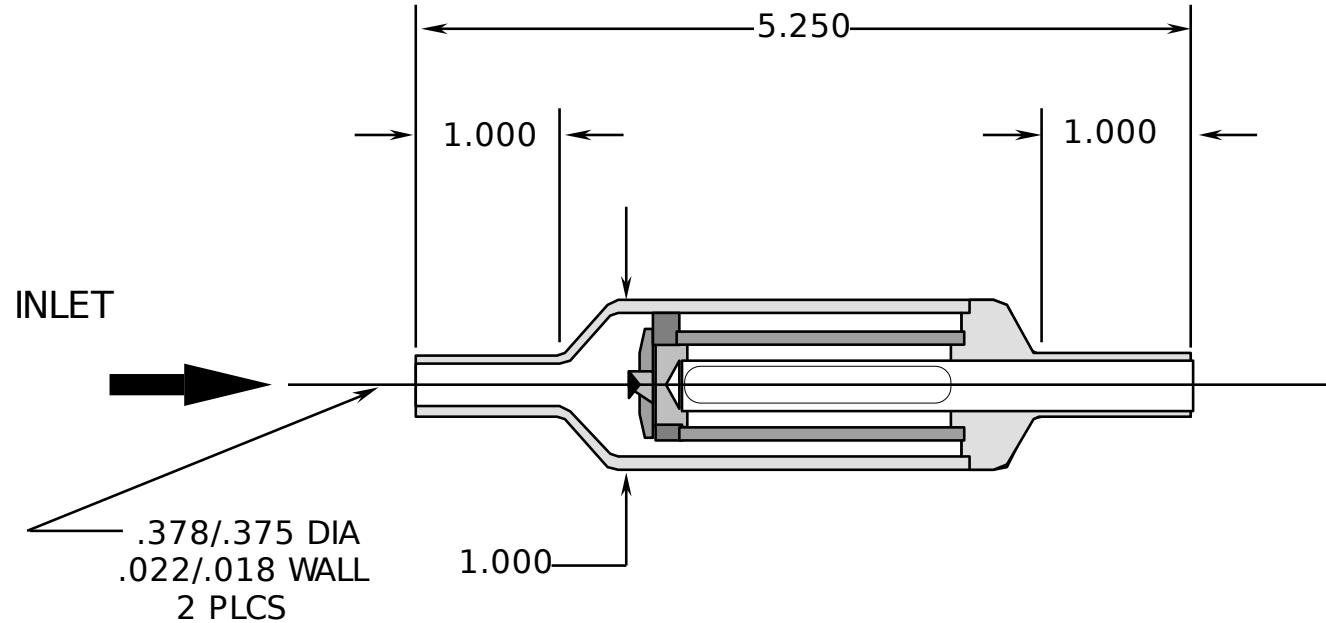
Qualification

NRL, NTS II, SOLRAD 9, 10,

Status: In-House



Propellant Filter



Characteristics

- 304L SS Body
- Titanium Filtration Element
- 25 μ Rating ABS
- Pressure Drop < 10 psia @ 300 psia
- Pressure: 325 psia Operating
488 psia Proof
- 1,040 psia Burst Demonstrated
- Weight: 0.26 lb

Status: In-House

Manufacturer

Vacco Industries
El Monte, CA
P/N: F1D10482-01

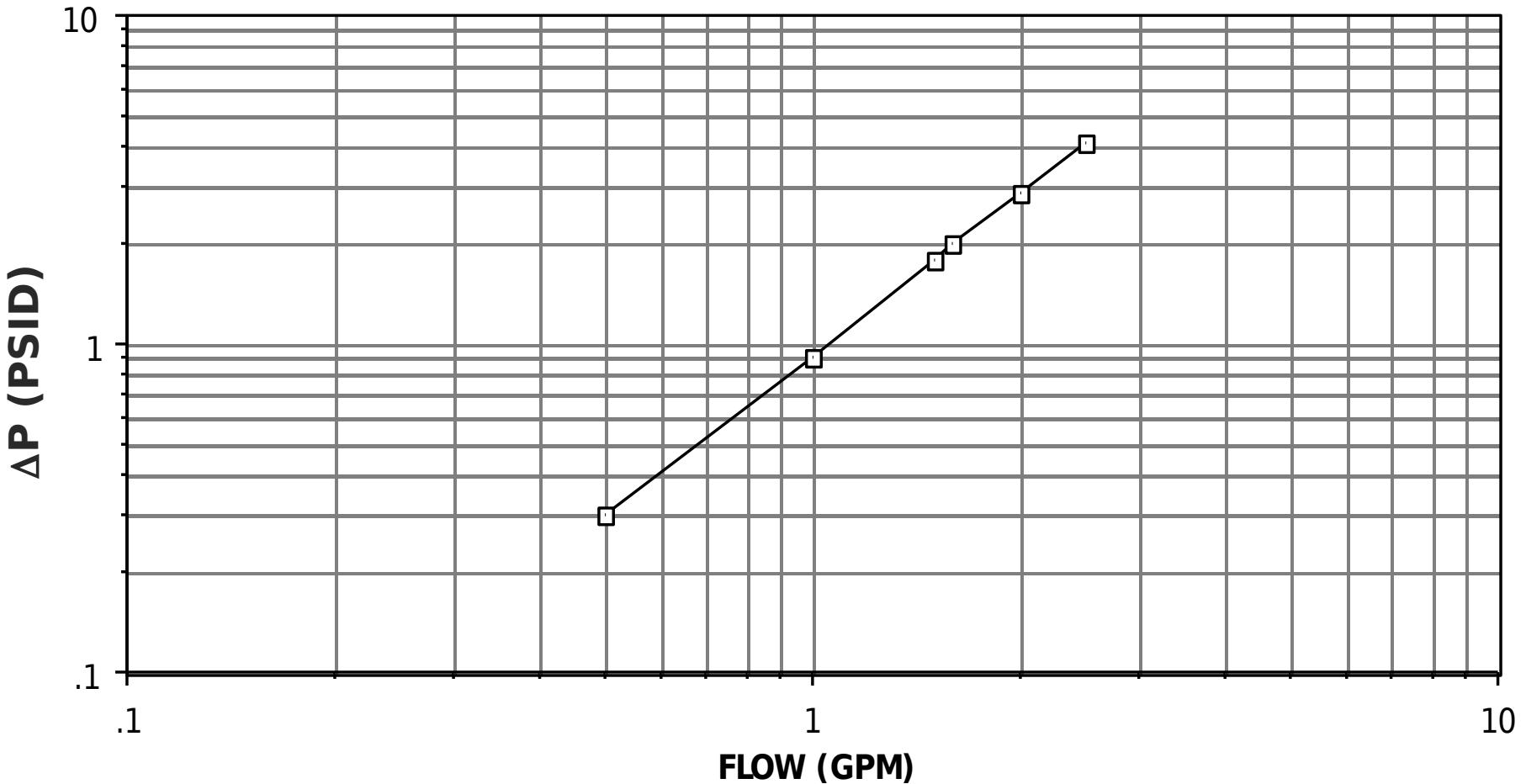
Qualification

Vacco, Hughes
INSAT, IABS



Filter Flow Characteristics

FILTER ATP DATA



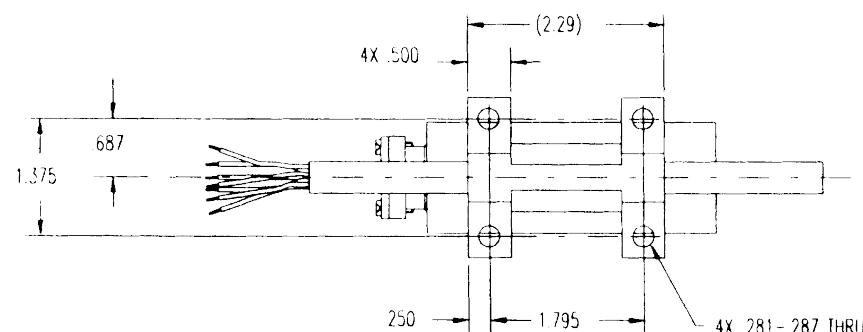
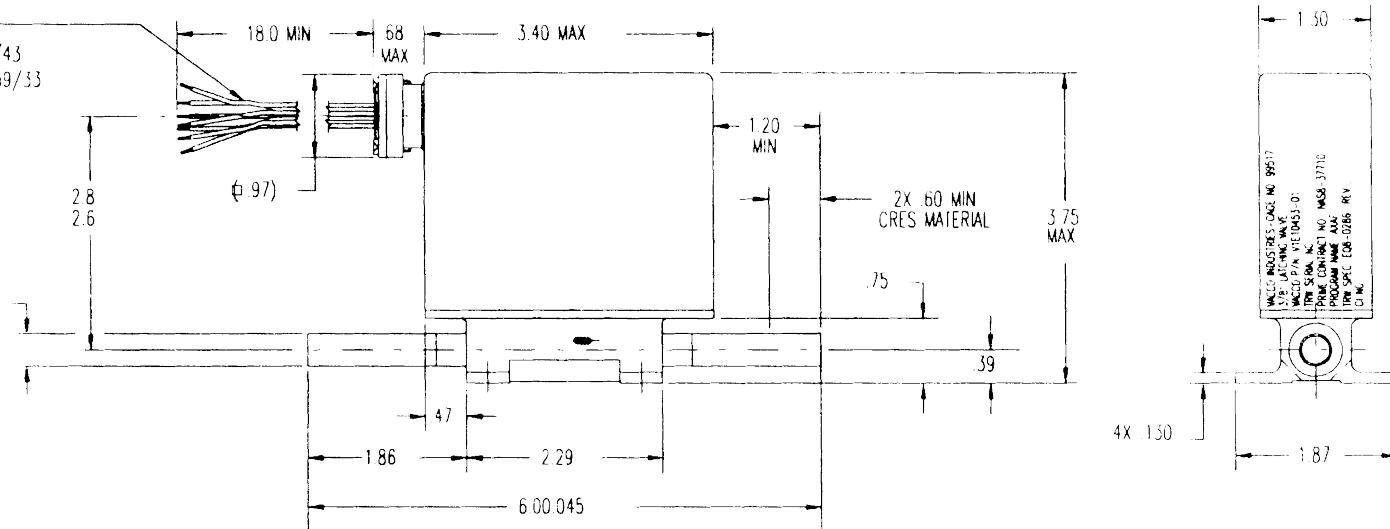


Latch Valve Interface

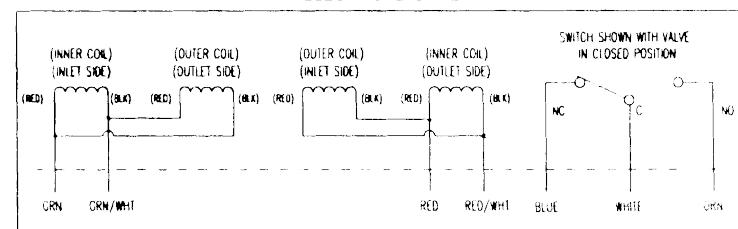
INTERFACE DIMENSIONS

7 WIRES, 22 GAGE
COIL WIRES PER MIL-W-22759/43
SWITCH WIRES PER MIL-W-22759/33

2X .375-.377
019-.021 WALL



ELECTRICAL SCHEMATIC

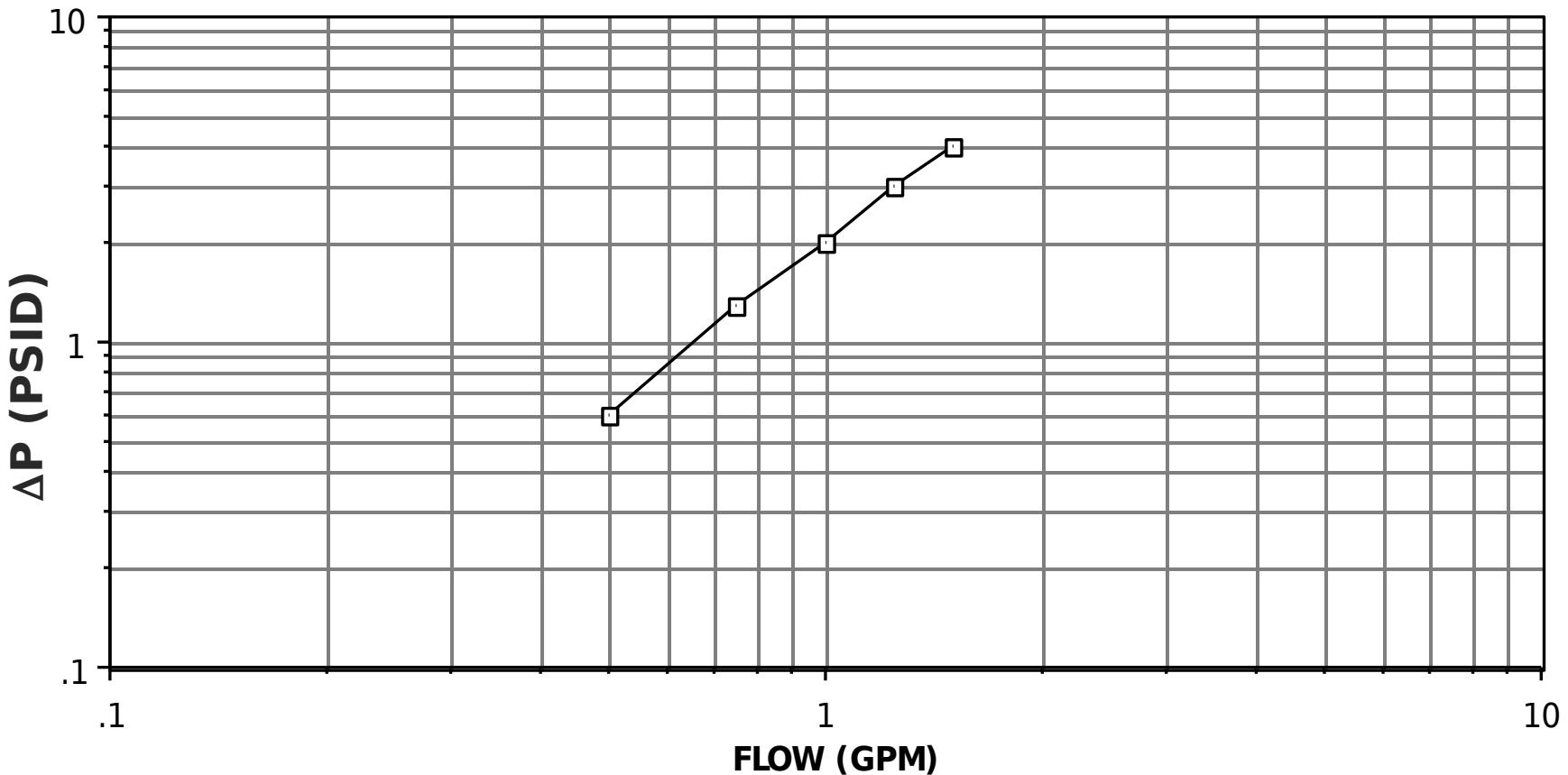


prop_tnk_latch_vlv.tif



Latch Valve Flow Characteristics

QUALIFICATION UNIT DATA





Materials

- All Materials in the Propellant & Pressurant System Have Demonstrated Compatibility With Hydrazine, IPA, & Deionized Water
- Corrosion Resistant Steels
 - 304L, 347, 17-4, 17-7, 430, 301, 302, 303
- Aluminum
 - 2219, 5086, 1100
- Titanium 6Al-4V
- Inconel 600, 625
- Elastomeric Seals
 - 515-80 EPR



RCS Tubing

- **304L CRES Material Preparation**
- **Control Environment**
- **Electro Polish Or Chem-Etched**
- **Ultrasonic Cleaning**
- **Welding**
- **Automatic Tube Welding System (Gas Tungsten Arc Process)**
- **Weld Schedules Developed For This Program**
 - Dye Penetrant
 - Proof
 - Leak
 - Burst
- **Production Welds**
- **Developed Schedule (Current Traces)**
- **Visual**
- **Proof**
- **Helium Leak**



Fluid Component Structural Integrity Design

- MIL-HNDB-5 Material Properties Are Used
- 304L CRES Annealed
 - Ultimate Strength Tension 65.8 ksi @ 140°F
 - Ultimate Strength Sheer 44.1 ksi @ 140°F
 - Yield Strength Tension 28.8 ksi @ 140°F
 - Yield Strength Shear 19.3 ksi @ 140°F
- 301 CRES
- 316 CRES
- Titanium 6Al-4V
- 2219 Aluminum
- 1100 Aluminum
- Design Factors
 - Proof > 1.5 x MEOP @ 140°F No Yield
 - Burst > 4 x MEOP @ 140°F No Rupture



Analysis

- **Analysis Performed To Date**
 - Trade Studies
 - Component Specifications & Procurements
 - Propellant Ullage vs Temperature
 - Detailed Helium Pressure Budget
 - Propellant Utilization Profiles
 - Plume Heating Analysis
- **Analysis To Be Performed**
 - Update Analysis Performed for CDR
 - Total Propellant Outage Analysis (3 Sigma)
 - Prop Flow/Pressure Drop
 - Component Structural Integrity
 - Tanks
 - Valves
 - Lines



Component Testing Plans

- Propellant Tanks
 - Atlantic Research Corporation (ARC) Deliver 2 Flight Units In 12 Months
 - Conduct Diaphragm Air Reversal Testing Required to Characterize Diaphragm ΔP
 - Expulsion Tests Will be Required to Characterize CG Control
- 22N (5 lbf) Thruster Valve
 - Procure Valve Similar to CLEMENTINE
 - Hot Fire ATP @ Hamilton Standard Planned To Recertify Thruster With New Valve
- 1N (0.2 lbf) Thruster Valve
 - Valve Design Modification
 - Hot Fire ATP @ Hamilton Standard Planned To Recertify Thruster With New Valve
- Component Acceptance Test for In-House
 - Latch Valve, Transducer, Fill Valve, Pyro Valve



RCS Flow Model Testing

- Configuration
 - Hydrazine Tank Assembly
 - Pressure Transducers
 - Flight Like Filter and Latch Valve
 - Laboratory Fluid Lines, Pressurant Supply, Simulator & Instrumentation
- Special Instrumentation
 - Tank Outlet & Inlet Pressures
 - Flow Rate
 - Temperatures Throughout Assembly (Lines, Valves, Transducers, Gas)
- Test Setup Checkout
 - Fixed Supply Pressure (Short Duty Cycles)
- Monitor Pressure Variation
 - Flow Rate (Nominal)
 - Valve & Transducer Use Options (Typical & Worst Case Duty Cycles)



RCS System Level Tests

- **Environmental Test Configuration: Complete RCS Installed On Structure**
 - **Spin Balance, Thermal Vacuum, Thermal Balance, Random Vibration, Acoustic, Pyroshock, EMC/EMI, Structural Loads, Modal Survey**
- **Functional Tests (Before & After Environmental Tests)**
 - **Leak Checks (Latch Valves, Thrusters, Pressure Control Valve, Seals)**
 - **Flow Checks Using Gas**
 - **Function Pressure Assemblies**
 - **Thruster Valve Characterization**
- **Performance Test**
 - **Validate RCS Procedures & System Operation**
 - **Propellant & Pressurant Servicing**
 - **Subsystem, MAGE & EAGE Checkout**
 - **Subsystem, MAGE & EAGE Operation**
 - **Subsystem & MAGE Safing**



RCS Component & System Test Matrix

Level of Assembly	Item	Unit Type	Test Requirements																								Comments			
			Mechanical Stress	Loads (Static + Dynamic)	Random Vibration	Acoustic	Pyrocs	Leak	Proof Pressure	Leak	Mechanical Fit	Leak	Draught Rating	Spin Balance	Magnetic R31419	Conducted Emissions (CE01)	Conducted Emissions (CE02)	Conducted Susceptibility (R3101)	Conducted Susceptibility (R3102)	Conducted Susceptibility (R3103)	Conducted Susceptibility (R3104)	Conducted Susceptibility (R3105)	Electrical Power Surge	Signaling Control Circuits	Radiated Emissions (RE02)	Electrostatic Discharge	DC Power Quality	Number of Thermal Cycles	Thermal Design Verification	Bakeout
RCS Subsystem	AKM	F	-	A/T	Q	-	-	1	1	-	-	Q	1	-	-	-	-	-	-	-	-	-	-	-	-	-	+4 / +32	-6 / +42		
	Propellant Tank	PF	-	A/T	1	-	-	1	1	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+7 / +30	-3 / +40		
	Pressurant Tank	PF	-	A/T	1	-	-	1	1	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+7 / +40	-3 / +50		
	Thruster 5.0 Lb	PF	-	A/T	1	-	-	1	1	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+7 / +40	-3 / +50		
	Thruster 0.2 Lb	PF	-	A/T	1	-	-	1	1	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+7 / +40	-3 / +50		
	Propellant Lines	PF	-	A/T	-	-	-	1	1	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+7 / +40	-3 / +50		
	Fill Valves	PF	-	A/T	Q	-	-	1	1	1	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	+7 / +40	-3 / +50			
	Pressure Transducer	PF	-	A/T	Q	-	-	1	1	1	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	+7 / +40	-3 / +50			
	Propellant Filter	PF	-	A/T	Q	-	-	1	1	1	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	+7 / +40	-3 / +50			
	Propellant Latch Valve	PF	-	A/T	1	-	-	1	1	1	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	+7 / +40	-3 / +50			
	Pyro Isolation Valve	PF	-	A/T	Q	-	-	1	1	1	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	+7 / +40	-3 / +50			



Assembly & Installation Approach

- Components, Lines & Fittings Are Assembled In A Clean Environment
- Assembly Techniques Are Previously Qualified & Documented In Appropriate Procedures
- Maximum Use Of Off-Line Buildup & Acceptance Testing Of Subassemblies Will Be Used
- Subassemblies Will Be Acceptance Tested To Preclude Assembly Level Acceptance Problems (Visual, Proof, Leak, Cleanliness, Functional)
- Installations Can Be Accomplished In Logical Groupings, To Maximize Total Buildup Flexibility



RCS Tooling

- **Assembly & Weld Fixtures**
 - **Helium Pressurant Control Assembly**
 - **Gas Feed Manifolds**
 - **Thruster Clusters**
 - **Latch Valve Assembly**
 - **Tubing Assemblies (As Required)**



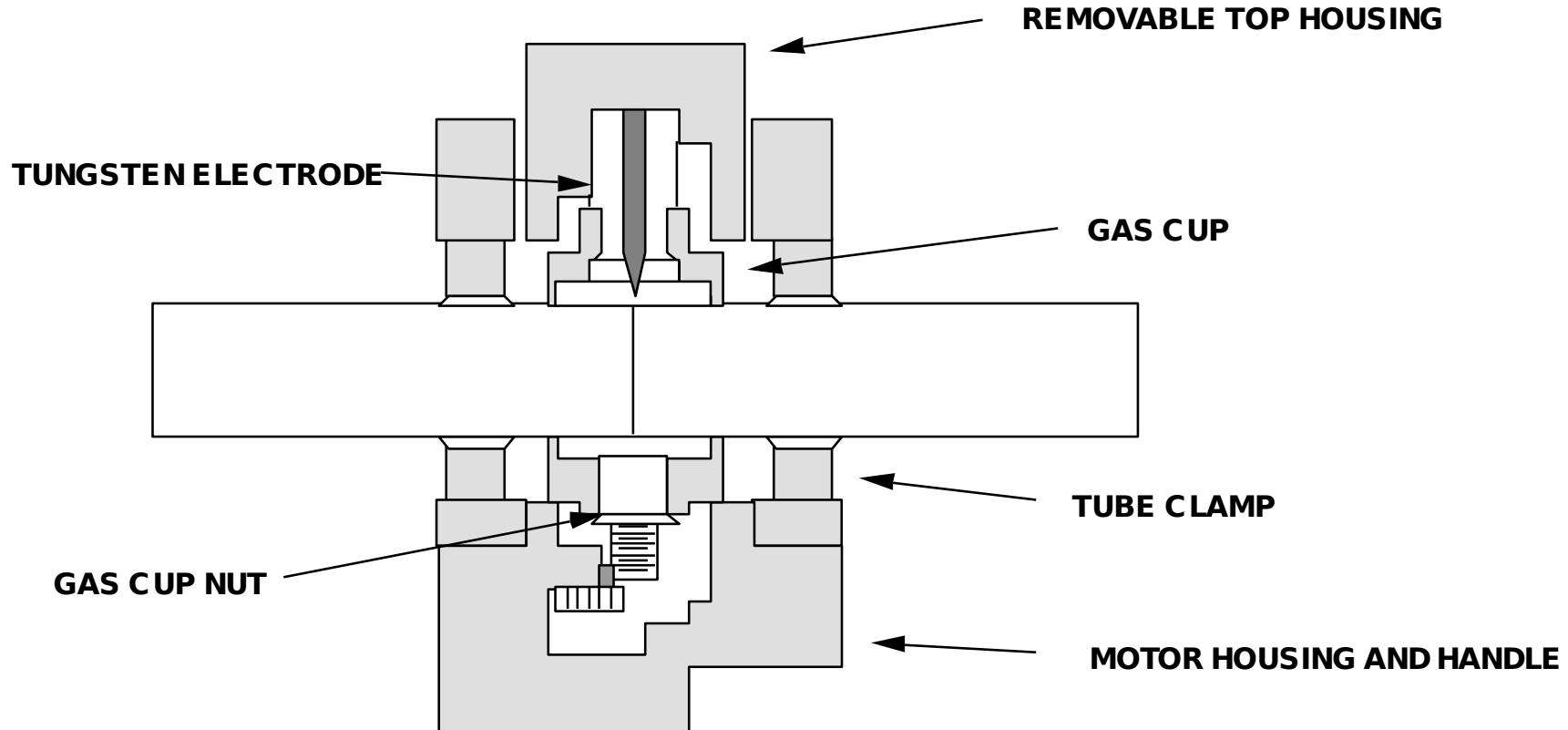
Welding

- **Tool Requirements**

- **Astro ARC, Model SP 100P, Portable & Programmable Tube Welding System**
 - **4 Welding Heads With Capability From 1/8 to 7/8" Tubing**
 - **3 Channel Strip Chart Recorder, Special Design For Weld Parameters**
- **Dynametrics, Model 700-09G, Hygrometer, With Linear Direct Reading Scale +20 To -80°C Dew/Frost Points**
- **American ACMI Boroscopes**
 - **Model 2570 AD .250 OD x 3 ft Flexible**
 - **Model BFO-05490A, 0.194 OD x 2 ft Rigid**
 - **Model BFO-03215A, 0.115 OD x 1 ft Rigid**
 - **Camera Attachment & Camera**
- **Liquid Argon, Regulator, Filters, Etc.**
- **Portable Down Flow Clean Room**
- **Weld Fixtures**



Weld Head





RCS Fill and Operational Sequence

- Connect Propellant Loading Equipment to FAME Fill Valves
- Propellant Tank Fill and Pressurize Operations
 - Open Fill Valves and Latch Valve
 - Vent Storage Blanket Pressure
 - Gas Side and Then Liquid Side
 - Pull Vacuum on Liquid Side of Tank and Propellant Manifolds
 - Low Pressure Fill Propellant To Limit Water-Hammer
 - Close Hydrazine Fill Valve and Latch Valve
- Pressurize Helium Tank Manifold
 - Close Helium Fill Valve
- Pad Operations
 - Red Tag Removal
 - Open & Verify Latch Valve
 - Safe & Arm Pin Removal
- Launch
- Post Booster Separation
 - Actuate Helium Isolation Valves Pressurize Tank to 375 psia (TBR)



Safety Provisions (1 of 2)

- **Design Provisions**
 - Propellant Compatible Material & Coatings
 - Conservative Material Properties In Design (MIL-HBK-5)
 - Leak Before Burst (Pressure Tanks)
 - Worst Case Environments Used In Design (Loads, Vibration, Acoustics, Temp)
 - Proven Storable Hydrazine Propellant
 - Development Program For All New Weld Schedules
 - Keyed Connectors: Test Cables & Helium & Fuel Fill & Drain Connections
 - Explosion Proof Electronics (MAGE)
 - Warning/Caution Labels



Safety Provisions (2 of 2)

- Manufacturing & Acceptance Provisions
 - Weld X-ray & Dye Penetrant Inspection Of All Pressure Vessel Welds
 - Proof Pressure Check All Pressurized Components & Assemblies
 - Weld Samples
 - Certified Welders
 - Helium Leak Check At Operating Pressure To Verify Feed System Welds
 - All Fluid Elements Cleaned Before Assembly; Assembled In Clean Areas & Protected
- Ground Operations Provisions
 - Proven Procedures
 - Helium Pressurant Tanks Pressurized At KSC
 - Fluids Are Isolated Prior To Activation By Pyrotechnic Isolation Valves
 - Low Pressure ACS Propellant Storage Prior To Pressurization
 - Includes Launch (Activated Launch Under Evaluation)



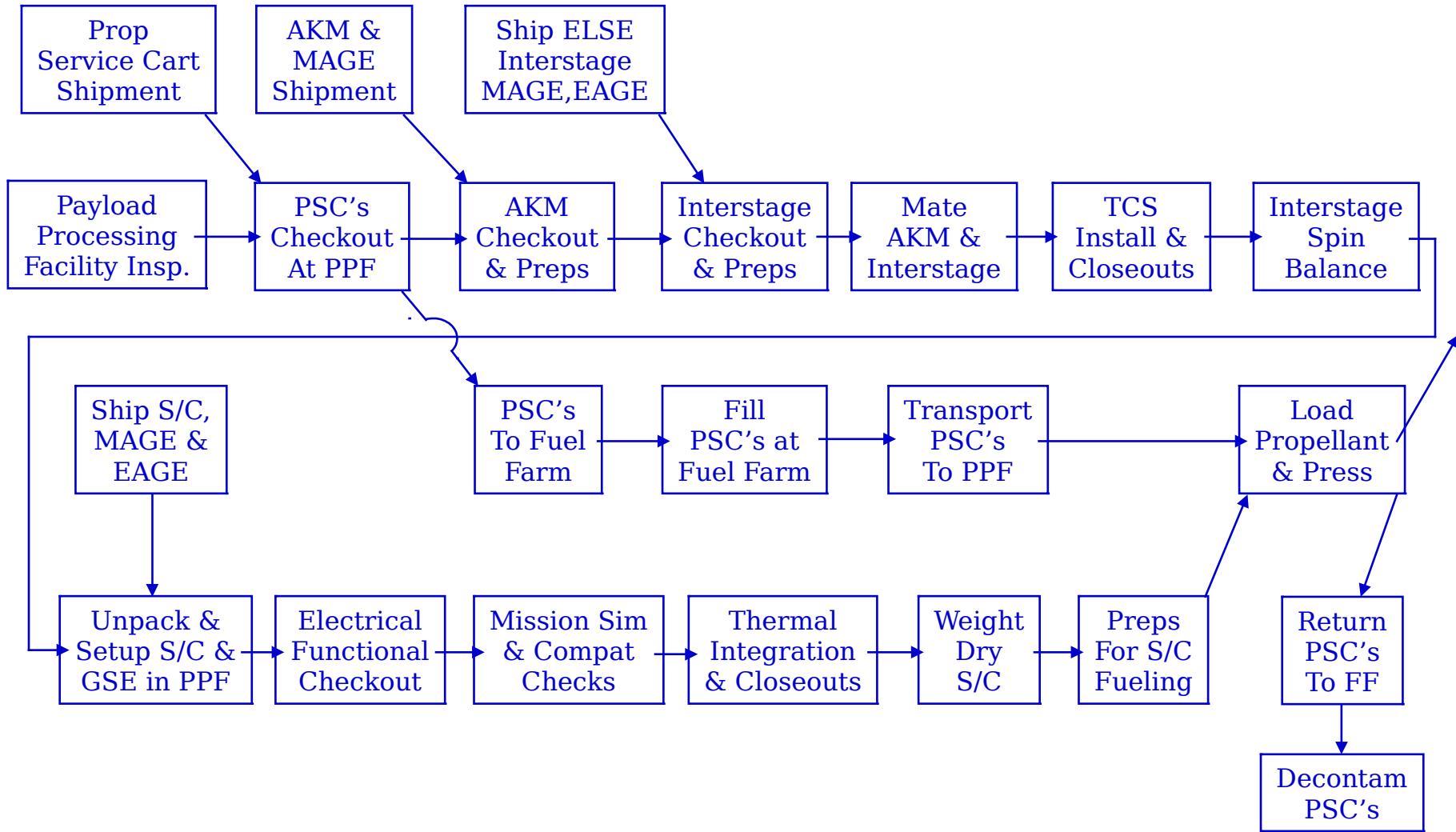
RCS Field Operations Documentation List



- **TOP-RC-TBD, RCS Component Functional, Flow & Leak Test Procedure**
- **TOP-RC- TBD, N2H4 Propellant Servicing Cart, Loading Procedure**
- **TOP-RC- TBD, N2H4 Propellant Servicing Cart, Offloading & Decontamination Procedure**
- **TOP-RC- TBD, Spacecraft N2H4 Tank, Loading and Pressurization Procedure**
- **TOP-RC- TBD, Spacecraft N2H4 Tank, Depressurization, Offloading & Decontamination Procedure**
- **TOP-RC- TBD, N2H4 Propellant Servicing Carts, Calibration Procedure**

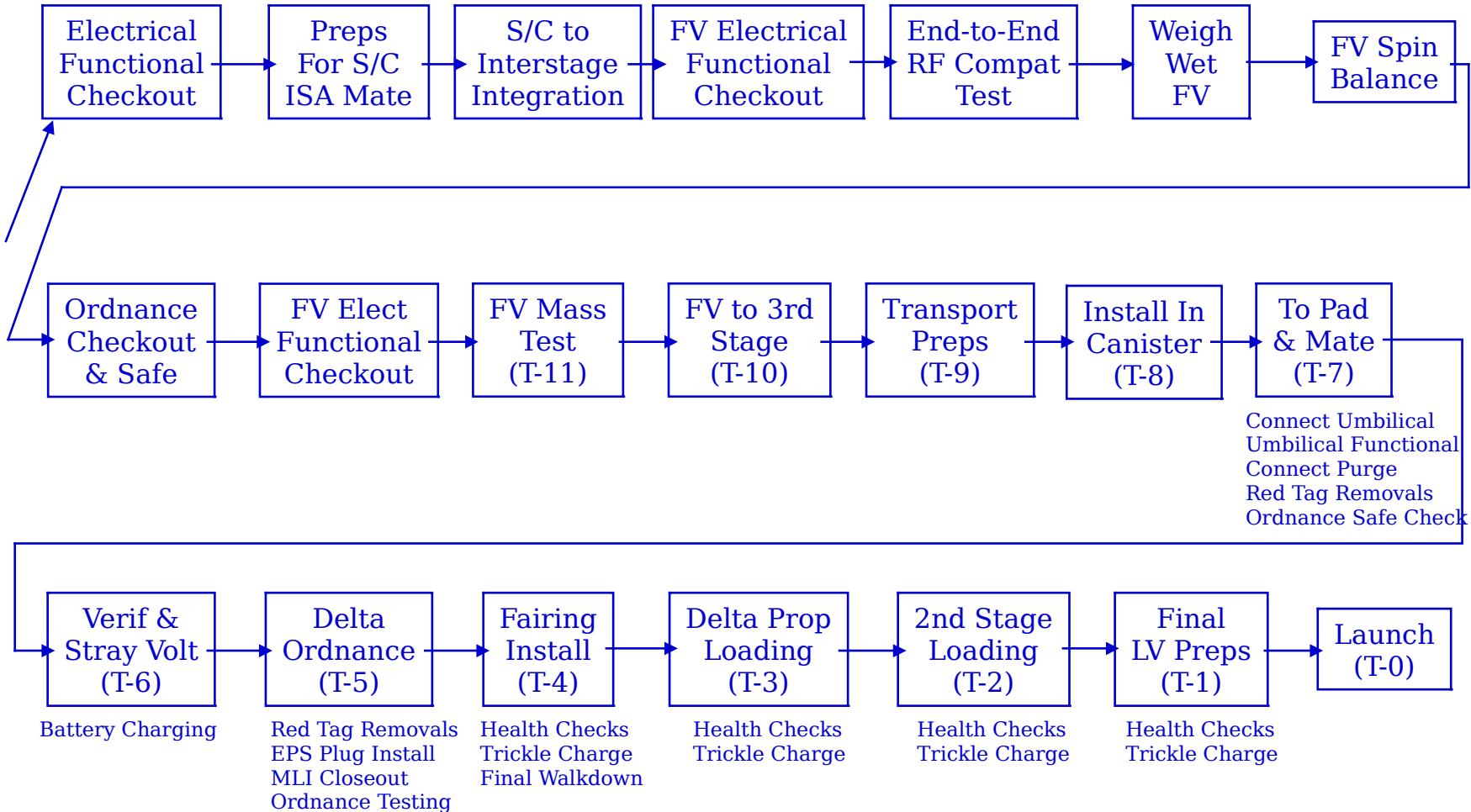


Field Operations Flow (1 of 2)





Field Operations Flow (2 of 2)





Field Operations Requirements

- Requirements For FAME Field Operations Captured in Following Documents:
 - NCST-ICD-FM002, FAME Spacecraft to Launch Vehicle Interface Requirements Document
 - EWR 127-1 Tailored as detailed in NCST-D-FM010, FAME System Safety Program Plan
 - KHB 1710.2D, Kennedy Space Center Safety Practices Handbook
 - NCST-D-FM021, FAME Training and Badging Plan for KSC and Eastern Range Operations
 - NCST-D-FM023, FAME Field Procedure Guideline
 - FAME Launch Site Support Plan for KSC/ER Operations
 - FAME Transportation Plan for KSC/ER Operations
 - FAME Communications Plan for KSC/ER Operations



Safety Provisions (1 of 2)

- Propellant Cart Design Provisions
 - Propellant Compatible Material & Coatings
 - Explosion Proof Electronics
 - Warning & Caution Labels
- Ground Operations Provisions
 - Proven TOPs (Technical Operating Procedures)
 - TOPs Will Be Approved By KSC Safety
 - Trained Personnel
 - Dedicated Personnel
 - SCAPE Trained
 - Personnel Will Have Loaded Referee Propellants Using Actual TOPs
 - Personnel Experienced in Handling Propellants



Safety Provisions (2 of 2)

- Personnel Access to Hazard Areas Will Be Limited
- Total Separation of MAGE Oxidizer and Fuel Systems
 - During Oxidizer Servicing, All Fuel MAGE Equipment Will Be At the Fuel Farm
 - During Fuel Servicing, All Oxidizer MAGE Equipment Will Be At the Oxidizer Farm
- PSCs Will Be Stored in Dedicated Propellant Storage Areas When Wetted With Propellant
- Venting Of Non Hazardous Gases Only
- Catch Tanks For Emergency Propellant Drain and Storage
- Flush Fluids For Neutralizing Propellant Spills
- Dedicated Storage For Contaminated Flush Fluids
- Propellant Spill Containment/Mop & Sop Kits
- Vapor Detectors Will Be Monitored By Safety Whenever Propellants Are In the Processing Facility



Range Support Requirements

(1 of 3)

- Hazardous Processing Facilities
 - Class 10,000 Clean Room
 - Propellant Service Area, With Waste Management For N2H4
 - 90 ft Candles Lighting @ 3 ft Above the Floor
 - Facility Vents For Toxic & Non-Toxic Gases
 - Electrical Power, 120 VAC, Single Phase, 20 Amp
 - Potable Water
 - 5 Ton Overhead Crane
 - Intercom & Closed Circuit TV
- Transportation
 - Truck For Moving Propellant Service Carts & Equipment
 - Fork Truck For On & Off Loading Propellant Service Equipment



Range Support Requirements (2 of 3)

- Commodities

- Hydrazine (N2H4), 150 lb, Ultra Pure, (Exceeds MIL-P-26536 Requirements)
- Liquid Nitrogen (LN2), MIL-P-27401 Type II, Grade A 110 Liter Pressurized Container
- Gaseous Helium (GHe), MIL-P-27407, Type I, Grade A 1000 SCF, 6000 psig, 4 BX (10" X 51") Size Cylinders
- Gaseous Nitrogen (GN2), MIL-P-27401, Type I, Grade A 1200 SCF, 2250 psig, 4 K (9" X 55") Size Cylinders
- Gaseous Helium (GHe), MIL-P-27407, Type I, Grade A 1200 SCF, 2250 psig, 4 K (9" x 55") Size Cylinders
- Breathing Air, Tube Bank Trailers Or Compressor On Site
- Deionized Water/Distilled Water, >50,000 Ω Resistance, 55 gallons
- Sampling & Analysis For Each Commodity
 - Required Before Use Of Commodity



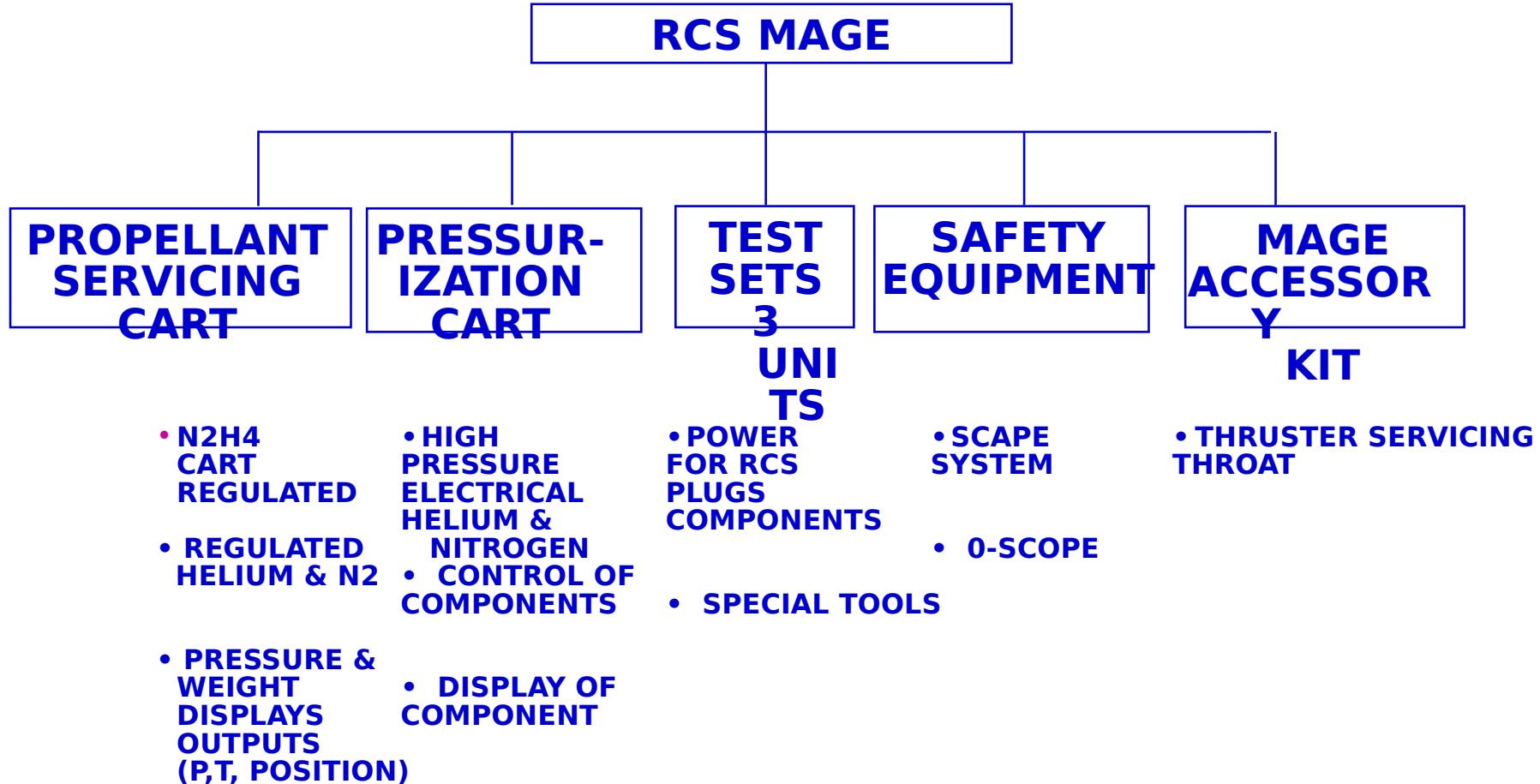
Range Support Requirements

(3 of 3)

- **PHE/SCAPE**
 - Medical Examinations If Ours Are Not Acceptable
 - SCAPE Certification Training For 6 people: CAT I & CAT IV
 - SCAPE Operations Support For 6 People for 5 Days
 - 2 Days For Loading & 3 Days For Clean-Up
 - CAT IV Required For Loading
 - CAT I & CAT IV For Clean-Up
 - Hydrazine(N2H4) Portable Toxic Vapor Detectors
 - Oxygen Monitoring
 - Personnel Protective Equipment ELSA 5 & 10 Minute Packs
 - Canister Type Gas Masks
- **Toxic Disposal**
 - 55 Galons Contaminated Water (N2H4)
 - Rags, Wipes & Plastic Bags Contaminated With Small Quantities Of Hydrazine
- **Cleaning/Decontamination**
 - Service For Flushed and Drained Lines and Fittings



RCS MAGE Elements





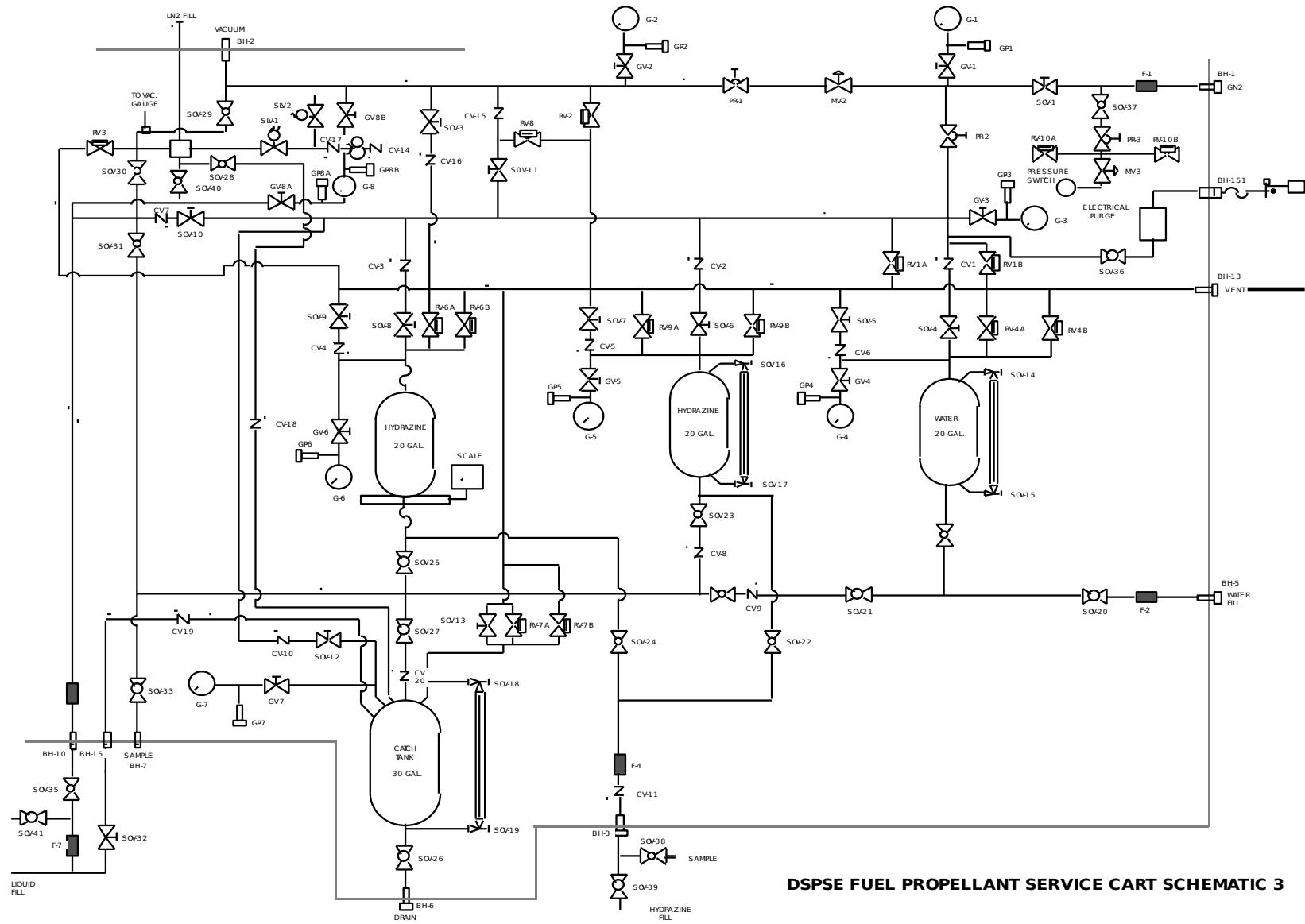
Hydrazine Propellant Service Cart



- **Description and Function**
 - Maximum Allowable Working Pressure of 55 psig
 - Tanks, Vacuum Pump/Cold Trap & Valves Are Mounted On Single Cart
 - 20 Gallon N2H4 Propellant Storage, 30 Gallon Catch Tank
 - Store Propellants Under Blanket Pressure Of Helium Or GN2
 - Deliver N2H4 Propellant at 3.0 lb/min Under Low Pressure To FAME
 - Receive Propellant If FAME Offload is Required
- **Safety Features**
 - System Minimum Design Burst Is 4X Working Pressure
 - Flex Hoses & Fittings Are Of Different Sizes Preclude Misconnection
 - Fuel Systems are Red Color Coded
 - Valves and Gages Are Easily Accessed and Identified On The Panels
 - Built-In Spill Containment At Disconnect Interfaces
 - Electrical Equipment Designed For Class 1, Div 1, Group C Atmosphere
 - Redundant Relief Valves
 - Connectors (Electrical & Fluid) Are Labeled
 - System Schematic Installed On The Panel Face



Fuel Service Cart





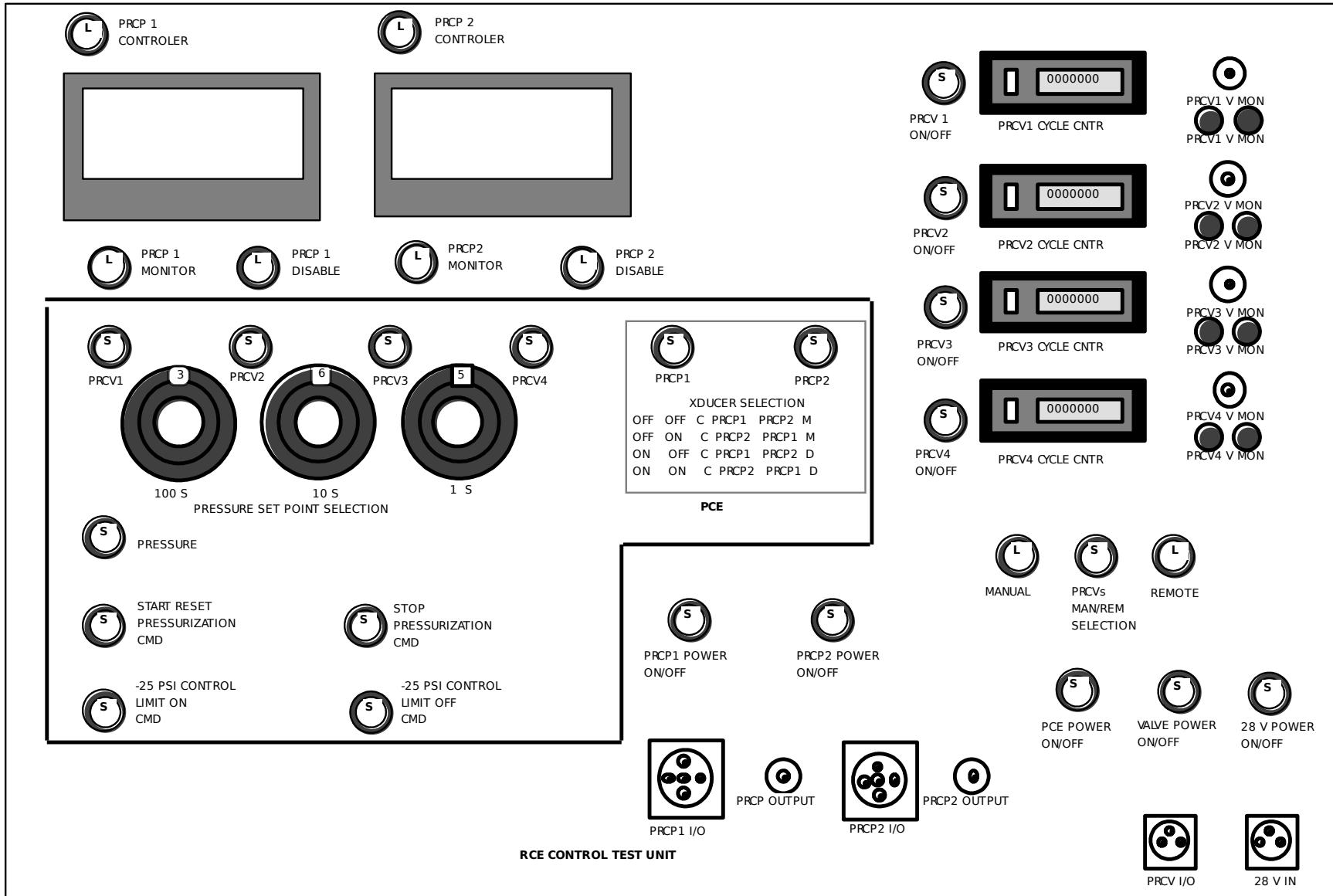
RCE Control Test Unit



- **Description**
 - **Switches, Meters, & Associated Electrical Hardware, Box Mounted**
- **Function**
 - **Simulates Spacecraft Control Electronics (RCE)**
 - **Used For RCS Checkout & Functional Testing**



RCE Control Test Unit Diagram





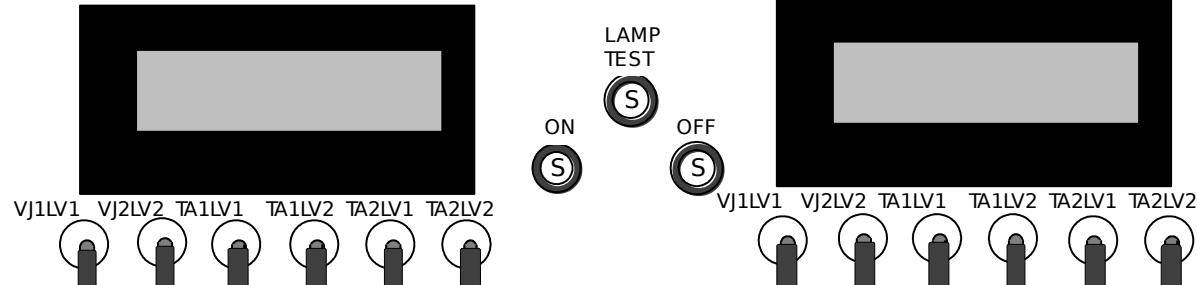
RCS Test Box

- **Description**
 - **Switches, Meters, & Associated Electrical Hardware, Box Mounted**
- **Function**
 - **Provides RCS Propellant Control**
 - Latch Valve
 - Thruster Valves
- **Used for RCS Check-Out & Functional Test**

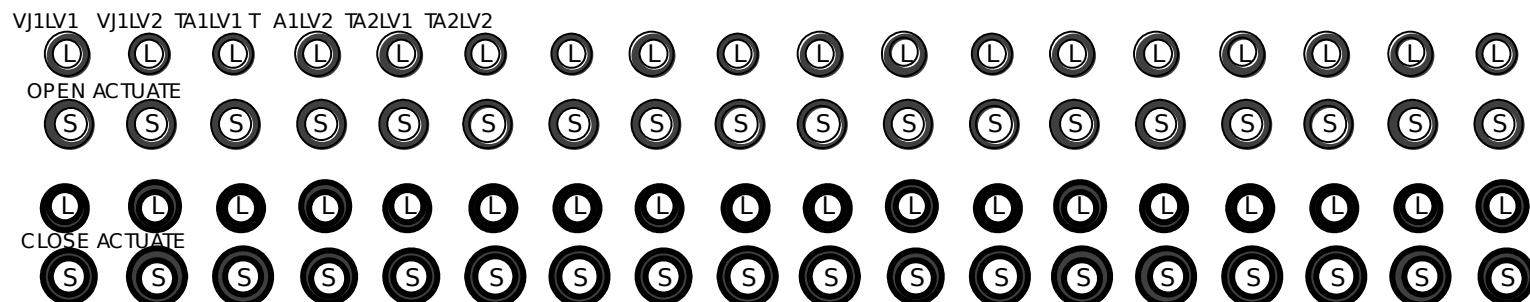


RCS Test Box Diagram

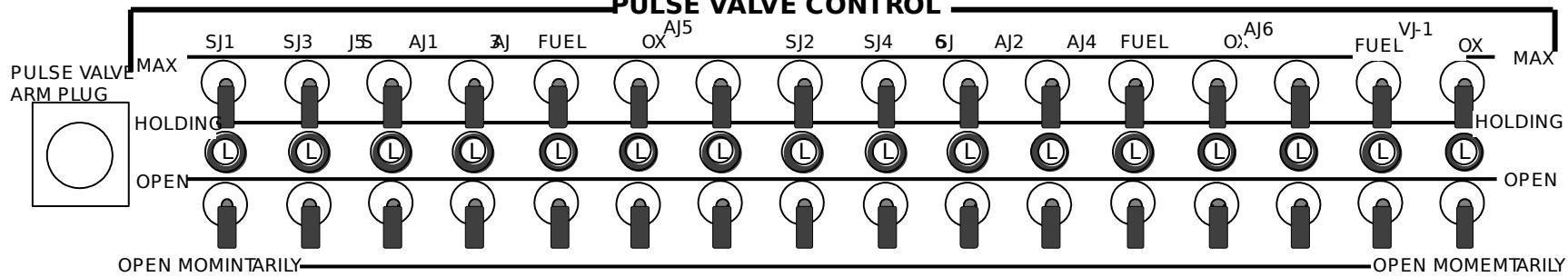
RCS TEST BOX



LATCH VALVE CONTROL



PULSE VALVE CONTROL



RCS TEST BOX

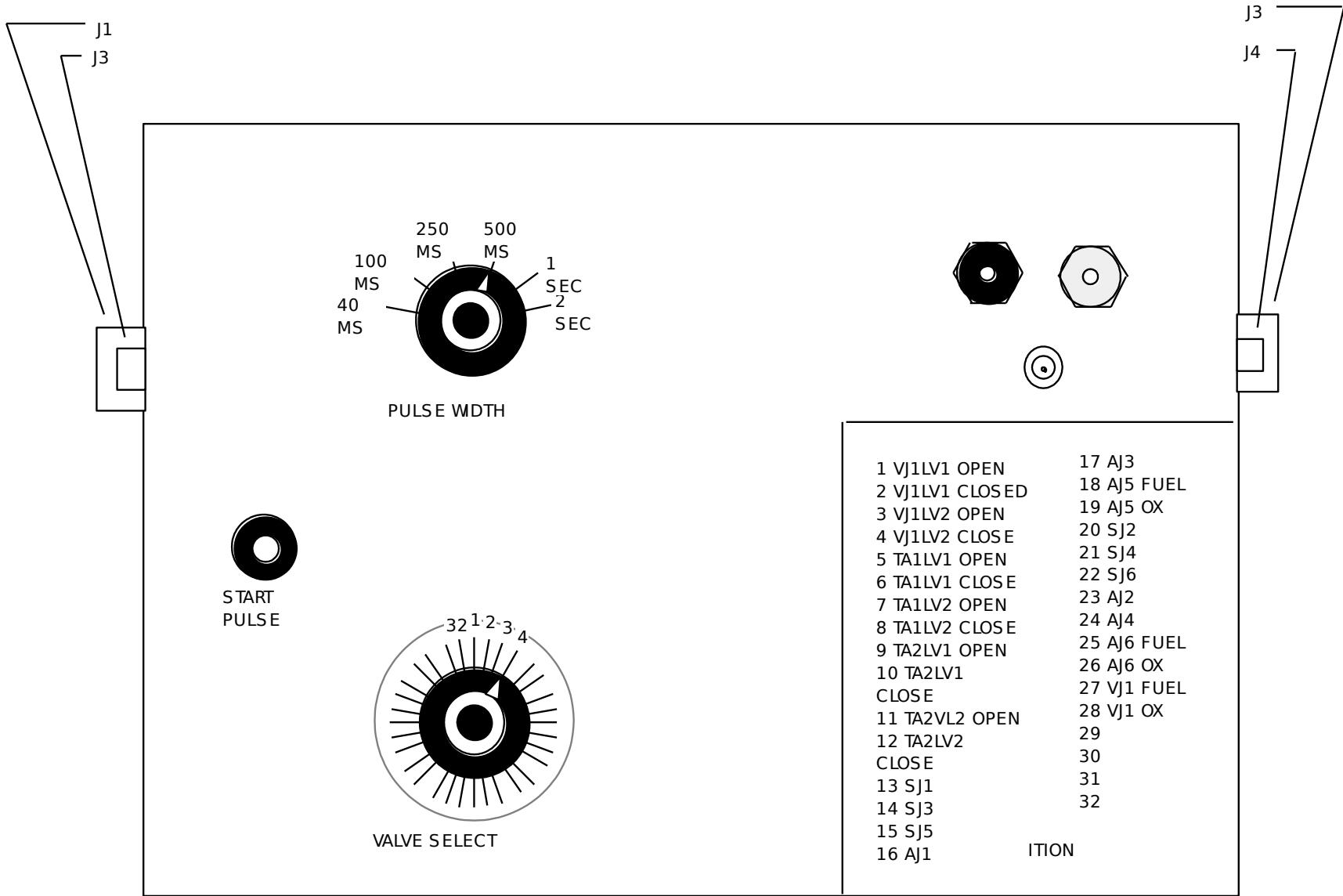


Valve Pulse Control Box

- **Description**
 - **Switches, Meters, & Associated Electrical Hardware, Box Mounted**
- **Function**
 - **Controls Thruster Valve Pulse Width**
 - **Pulses Valves Open For Specific Time Intervals**
 - **Used For RCS Checkout & Function**



Valve Pulse Control Box Diagram



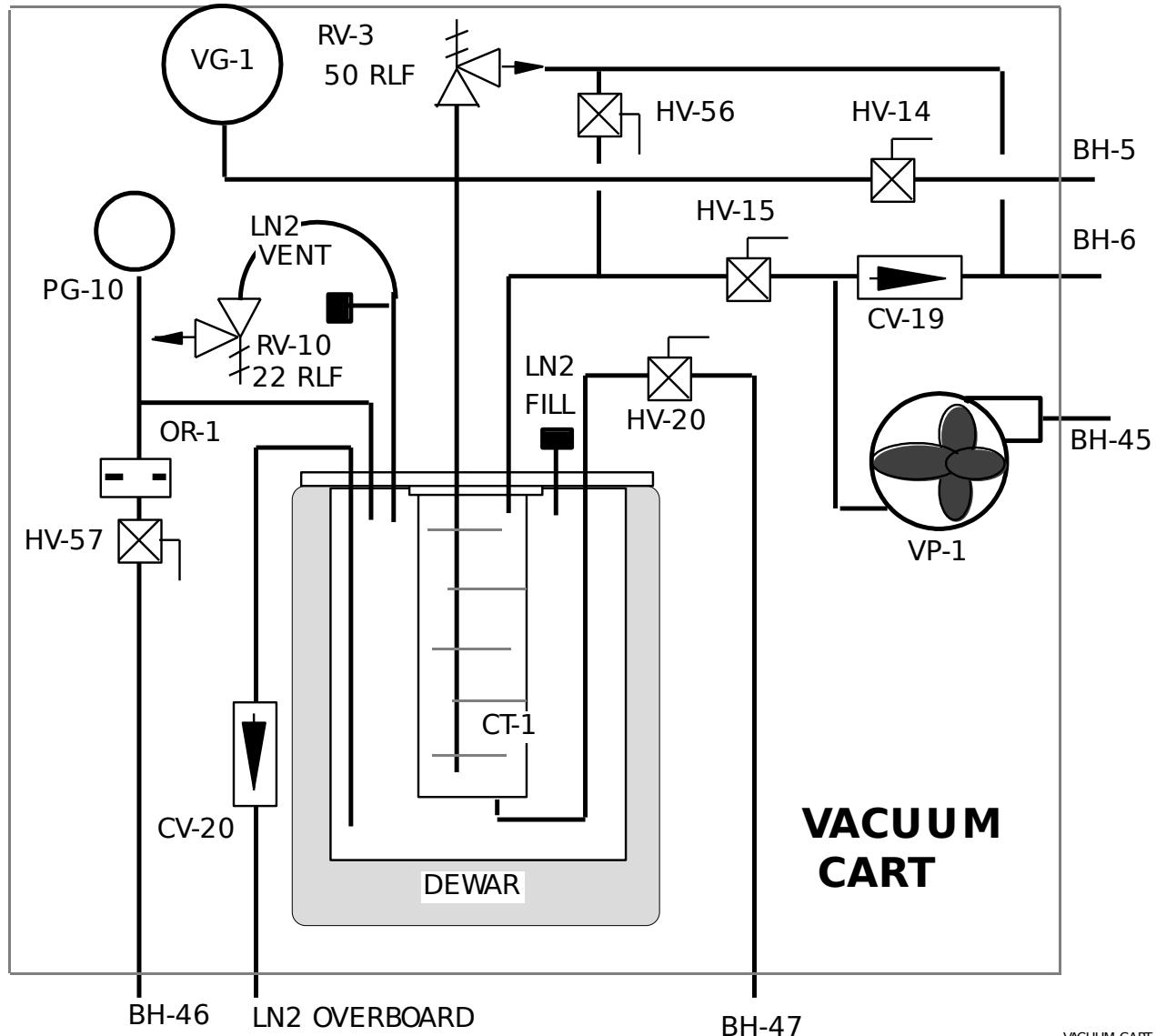


Vacuum Cart

- **Description**
 - **Vacuum Pump, Cold Trap, Associated Valves & Gauges Mounted On A Portable Cart**
- **Function**
 - **Evacuates Propellant Tank For Servicing**
 - **Evacuates Transfer Lines For Servicing**
 - **Evacuates Pressurant Tanks For Servicing**
 - **Evacuates Contaminated/Solvent Flushed Equipment For Decontamination & Dryout**



Vacuum Cart Diagram



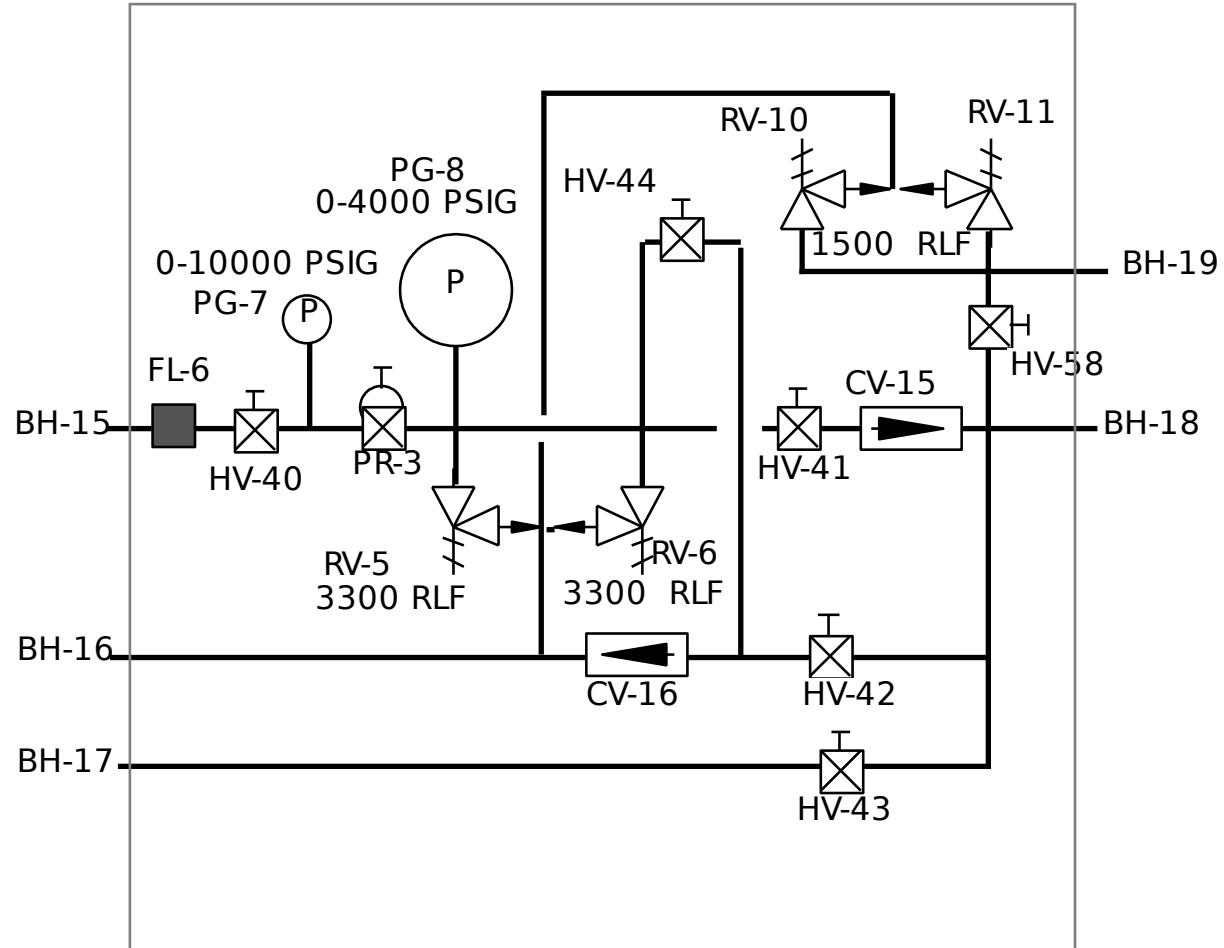


Pressurant Control Console

- **Description**
 - **Portable Panel Housing Monitor Gauges, Control Regulator, Control Valves, & Associated Hardware**
- **Function**
 - **Regulates/Controls Pneumatic Pressures (GN2 & GHe)**
 - **Pressurization Of Helium Tanks**
 - **Leak Checks & Valve Function**



Pressurant Control Console Diagram



Press. Control Console



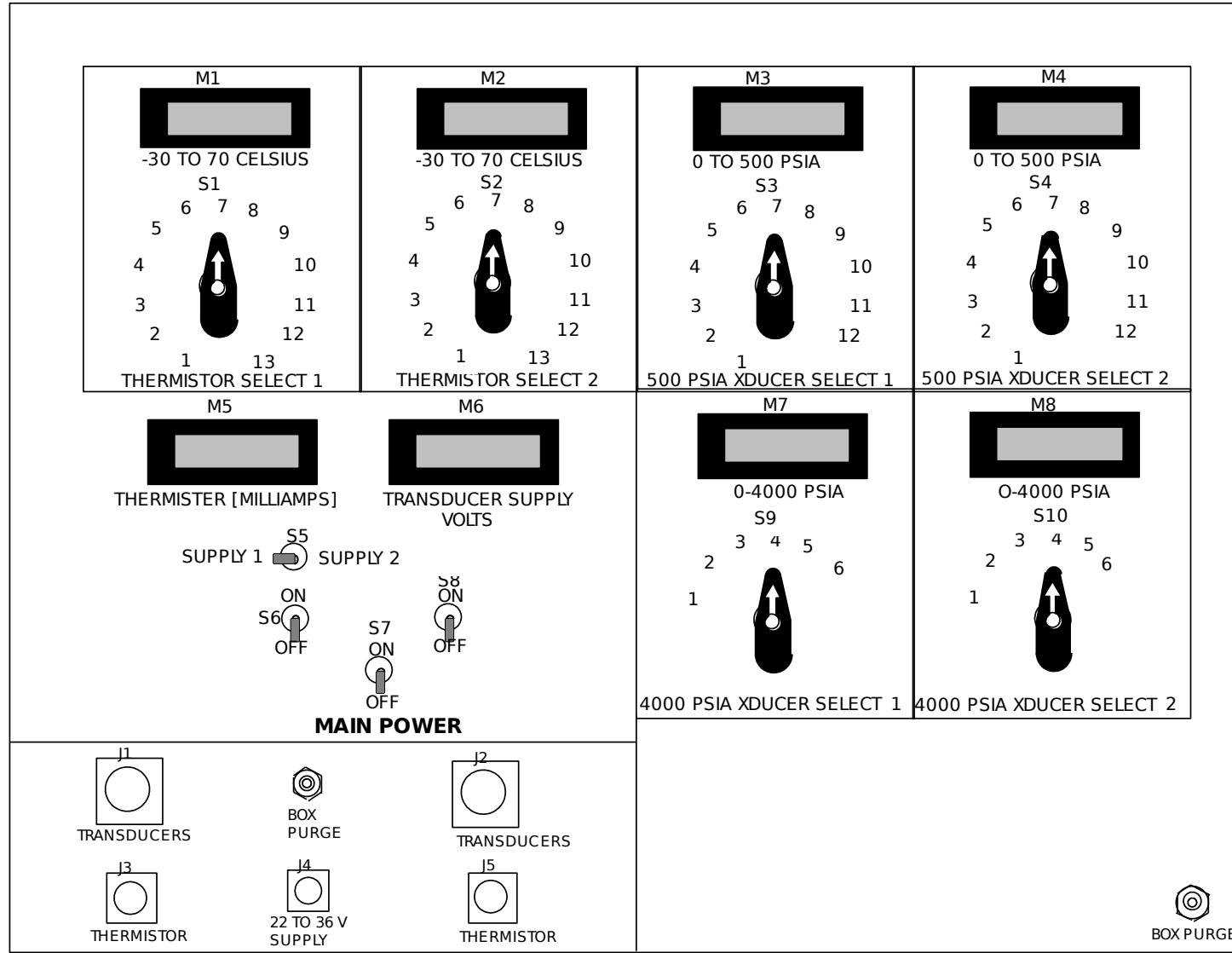
Pressure/Temperature Monitor Box



- **Description**
 - **Switches, Meters, & Associated Electrical Hardware, Box Mounted GN2 Purged**
- **Function**
 - **Provides Digital Read-out Of RCS Transducers & Thermocouples**
 - **Used In Following Tasks:**
 - **RCS Check-Out & Functional Testing**
 - **Propellant Servicing**
 - **Pressurant Servicing**



Pressure/Temperature Monitor Box Diagram





Additional Propulsion Issues

- Tight Schedule to Meet the Bus Integration Requirements
 - Expedited Procurement Process Required If Procurement is Delayed
- Mission, Thruster, and Tank Analysis Are Still Under Investigation
- SRM Offloading
 - How much to Offload
 - Offload Optimization
- SRM Nozzle Vendor Qualification
 - New Nozzle Vendor Requires Static Hot Fire Test
 - Cost of Approximately \$1M